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THE NATIONAL EXPORT EXPOSITION at Philadelphia was formally opened on Sept. 14, in the presence of the officials, invited guests and representatives of the army and navy and the diplomatic corps. The exposition was turned over to Governor Stone, of Pennsylvania, by Mr. W. W. Foulkrod, Vice-President of the Exposition; and Director-General W. P. Wilson explained the inception, purpose, plan and scope of the exposition. In brief, this purpose is to show the foreign consumer what the American manufacturer can make, and how cheaply and well he can make it. Gov. Stone welcomed the visitors, and said that this enterprise was the result of the work of two Philadelphia institutions, the Philadelphia Museums and the Franklin Institute, which have united to increase the exports of the country. Then Congressman W. P. Hepburn, of Iowa, Chairman of the Congress Committee on Interstate and Foreign Commerce, made the oration of the day, and eloquently pointed out the opportunities of this country in the way of supplying the world's markets and the necessity of so doing for the purpose of keeping our millions engaged in remunerative work. He believed that in this exposition was inaugurated one of the most important of aids to the American manufacturer and trader in capturing our share of the commerce of the world. The exhibits themselves are not yet completely installed; but in a week or two all will be in shape.

AIR BRAKES ON RUSSIAN RAILWAYS are made the subject of an interesting communication by Consul-General Holloway, of St. Petersburg, Russia, published in the advance sheets of Consular Reports for Sept. 18, 1899. This communication states that as the result of the ministerial order requiring all standard Russian railways to equip their freight cars and engines with the Westinghouse air brakes by Jan. 1, 1903, at a cost of several million rubles, the Westinghouse Co. has erected a fine plant, equipped with the latest improved American machinery, and is now employing a large force of men under experienced American engineers. The general manager is Mr. A. Kapteyn, of London, who is assisted by Mr. Walter Phillips, of Philadelphia, and by American experts in charge of the various departments. This order involves the equipment of 300,000 cars, as well as a large number of locomotives, 60,000 of which are to be fitted with Westinghouse air brakes and 240,000 with air pipes and couplings inside of three years. Mr. Holloway states that while in conformity with the decision of the Ministry of the Ways of Communication and of the extraordinary congress of representatives of the service of rolling stock and traction, summoned in January, 1899, on the question of the choice of the fundamental system of continuous automatic brakes for freight trains, the Westinghouse system of brakes is adopted, the introduction of other systems of continuous automatic brakes is allowed upon condition: (1) Of the previous trial of the new system on trains of local circulation, during not less than three years, for its thorough trial under the ordinary conditions of working; (2) of the possibility of the combined action of the new system with Westinghouse's system; (3) of the mutual interchangeability of the connections (couplings); (4) previous to the introduction of the new system into direct communication, the question of its practical suitability for this object is to be considered by the congress of representatives of the service of rolling stock and traction, and the ratification of the conclusion of this congress is to follow the usual course.

A LARGE CANADIAN STEEL PLANT is planned by the Dominion Coal & Steel Co., which has been organized with a capital of $20,000,000. The plant will be located at Sydney, Cape Breton. The company owns its own mines at Bell Island, in Conception Bay, and has a coal mine nearby. The iron is hematite, with the ore ledges in the form of segregated cubes formed by transverse cracks. No. 3 seam, now being worked, is 10 ft. thick, 300 ft. wide, and 3 miles long; and it is estimated that there are 28,000,000 tons of iron ore available on the island without following the veins under the sea. The ore is carried to the wharves by cars hauled by an endless cable; it it automatically dumped into pockets, from which the ships are loaded; the cost of the ore f. o. b. is said to be about 30 cts. per ton; and it can be laid down at the blast furnace for 50 cts. per ton. The company is also entitled to the Dominion bounty of $2 per ton for iron smelted in Canada, and $3 per ton for steel made in Canada. The company expects to turn out 800 tons of steel daily, netting it $5 per ton in bounties alone, or $8,000 per day. The company will make its own coke, and immense coke ovens are now being built; and one of the blast furnaces will be working in August, 1900. The directors of the company include Sir William Van Horne and R. B. Angus, of the Canadian Pacific Railway; R. G. Reid, the Newfoundland railway magnate; James Ross, of Montreal, and Senator Cox, of Toronto. Two New Yorkers are on the directorate—A. H. Paget and H. F. Dimock. The master mind of the whole enterprise is H. M. Whitney, of Boston, who is president and managing director

THE RAPID GROWTH IN EXPORTS of American iron and steel is pointed out by the Treasury Bureau of Statistics. The statement issued covers each year from 1880 to 1899, inclusive, giving the production of pig iron in the United States, and the import and domestic export of manufactured iron and steel. Taking only every fifth year we have the following:

Year ending June 30,	American production of pig iron, tons.	Value of iron and steel manufactured, Imports.	Value of iron and steel manufactured, Domestic exports.
1880	3,835,191	$71,266,699	$14,716,524
1885	4,044,526	33,610,093	16,592,155
1890	9,202,703	41,679,501	25,542,208
1895	9,446,308	23,048,515	32,000,989
1899	*14,000,000	12,098,239	93,715,951

*Estimated by J. S. Jeans, Sec. British Iron Trade Assoc.

Mr. Jeans, in estimating the pig iron production of the principal iron-making countries of the world, credits the United States with 14,000,000 tons out of a total of 37,150,000 tons for 1899, as compared with 11,774,000 in 1898, out of a total of 32,610,000 tons. For 1899 he gives England second place with 9,500,000 tons; and Germany third, with 8,250,000 tons. The estimates for France and Belgium are 2,700,000 and 1,200,000 tons, respectively.

THE PORT ARTHUR SHIP CANAL is in operation; and on Sept. 8, the British steamship "St. Oswald," that entered on Aug. 13, went out through the canal with 75,000 bushels of wheat on board and drawing 17 ft. The remainder of her cargo will be put on in Sabine Pass by lighters; this includes 1,332,100 lbs. of flour, 322 tons of staves and 300,000 ft. B. M. of lumber, all consigned to Rotterdam. Another steamer is due to take a cargo of grain and flour to Liverpool.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a head-end collision on the Chicago, Rock Island & Pacific Ry., about 12 miles west of Iowa City, Ia., on Sept. 12. Two extra freight trains met on a sharp curve at the valley of two heavy grades, and were wrecked, killing four men and injuring seven others.——A bridge failure near Nebraska City, Neb., on the Missouri Pacific Ry., on Sept. 15, wrecked 21 cars and a locomotive, and resulted in the death of three men.

THE PIKE'S PEAK POWER CO., recently incorporated, proposes to develop 3,200 HP. for distribution to the mines in the neighborhood of Cripple Creek, Colo. The source of the water supply is Beaver Canyon, and a steel and rock dam will be built, having a storage capacity of 150,000,000 cu. ft. Two 30-in. steel pipes will lead the water to the power house, where a head of 2,300 ft. will be available. It is expected that the plant will be completed in six months, at a total cost of $500,000. R. M. Jones is the electrical and hydraulic engineer.

A LARGE POWER PLANT is being built at Rankin, Pa., by the Monongahela Light & Power Co. The building will be 95 × 333 ft. under cover, to which a structure for coal storage is to be added later. Six cross-compound Corliss engines, each of 1,000 HP., built by the Pennsylvania Iron Works Co., will be supplied with steam from Stirling water-tube boilers, equipped with Roney automatic stokers. The electrical equipment, which is being built by the Westinghouse Electric & Mfg. Co., comprises three 600 K-W. 550-volt direct-current machines for railway power, three 750-K-W. quarter-phase alternators and 10 125-light motor-driven arc-light units. The pumps and condensers will be furnished by the Worthington Co. The total cost of the plant will be $500,000, of which $375,000 is for machinery. James Bryan is the engineer having charge of the entire work.

A BRAZILIAN WATER POWER ELECTRIC PLANT is proposed to obtain 16,000 HP. from the Tiete River and transmit it electrically to the city of San Paulo, 24 miles distant. A masonry dam 1,000 ft. long and 35 ft. high will be built, and the water will be conducted by a steel conduit 12 ft. in diameter and a half mile long to the turbines, which will be furnished by the Stilwell-Bierce & Smith-Vaile Co., of Dayton, O. The electric transmission is to be at 20,000 volts, three-phase, and the current will be used by the San Paulo Tramway, Light & Power Co., which has offices at 621 Broadway, New York, and owns 104 miles of street railway track in San Paulo. The contract for the electrical equipment has not yet been let. The investment required is $5,000,000, which is to be furnished by American and Canadian capitalists, and it is estimated that two years will be required for the completion of the plant. Mr. F. S. Pearson, M. Am. Inst. Elec. E., is Consulting Engineer to the company; Mr. R. C. Brown is the General Manager, in charge at San Paulo, and Mr. Hugh L. Cooper, who sailed from New York Sept. 20, on the "Coleridge," is Chief Engineer of the hydraulic installation.

A 3-CT. STREET RAILWAY FARE forms part of the contract entered into between the town of Marshall, Mich., and the Jackson, Albion, Marshall & Battle Creek Street Railway Co. The company pays $5,000 per year to be applied to street paving, and agrees to sell 8 tickets for 25 cts. The franchise runs for 30 years.

COMPRESSED PEAT-FUEL is being successfully made by the Canadian Peat Fuel Co., of Stratford, Ontario. The peat comes from a swamp nearby, with an area of 40,000 acres and a peatbed from 1 to 20 ft. thick. This peat is cut and air-dried; it is then pulverized, passed through a picker and to a hopper which automatically feeds into a 2-in. steel tube, 15 ins. long. The pulverized peat is forced through this tube by pressure and formed by dies into cylinders 3 ins. long and almost as dense as anthracite coal. The fuel does not break up and is weatherproof, owing to the glaze given it by frictional contact with the dies. It weighs 83 lbs. per cu. ft., as compared with 73 lbs. for bituminous coal and 93 lbs. for anthracite. It has been tested in locomotives, showing a thermal value of 100 lbs. of peat equal to 95.15 lbs. of coal. Tried in the power house of the Metropolitan Street Railway, of Toronto, it was found that the heat produced was much greater than that of coal, but it was 8% deficient in lasting power. The cost of manufacture, says U. S. Consul A. G. Seyfert, of Stratford, is 60 cts. per ton under the best conditions. In Ontario hardwood for fuel is now worth $6 to $8 per cord; soft wood, $3 to $5; and all coal costs $6 per ton. It is estimated that there are 100,000 acres of peat bog in Ontario alone, principally in the counties of Perth, Welland and Essex. The above company was organized only one year ago.

THE INDIANA NATURAL GAS SUPPLY, says State Geologist Blatchley, in his annual report, is growing less in pressure and the quantity is limited. During the last five years all pipe lines have been extended towards the heart of the field and this center is now reduced to less than 150 sq. miles in area. In this practically undeveloped center the pressure has been reduced from 264 lbs. in 1895 to 181 lbs. in 1898; and the average rock pressure of the entire field which was 191 lbs. in November, 1897, was only 173 lbs. in November, 1898. The average pressure at which salt water overcomes gas, and necessitates the abandonment of the well, is probably between 130 and 150 lbs. to the sq. in. In the western portion of the field already abandoned this pressure was 250 lbs.

THE ILLINOIS RIVER BRIDGE at Marquette, Ill., which is now being built for the Indiana, Illinois & Iowa R. R., will be a single-track steel structure with three through-truss steel spans. The draw-span will be 365 ft. long, with a headway of 10 ft. above high water, and will be flanked by a riveted triangular truss-span of 122 ft. at each end. The approaches will be pile trestles, about ⅝ mile on one side and ¼ mile on the other side of the bridge. The contractors for the masonry substructure are Barron & Peace, of Marseilles, Ill. The contract for the superstructure has been let to the Wisconsin Bridge & Iron Works, of Milwaukee, Wis. This bridge, and the Vermillion River bridge on the same road, were designed by Mr. August Ziesing, M. Am. Soc. E., 1323 Monadnock Block, Chicago, who is Consulting Engineer for Bridges for the I., I. & I. R. R.

AN ELECTRIC RAILWAY WITH SIDE RUNNING TROLLEY.

The accompanying cuts are reproduced from photographs taken at Blackpool, England. The street railway of this place has been in operation since 1885, and is thus one of the pioneer electric roads of the world.

The system originally installed was an open conduit, as may be seen in the pictures, but the conduit has given much trouble. The road runs for a considerable distance along the beach, and in times of heavy weather the conduit was often completely filled with sea water, rendering the operation of the road impossible. On the other hand, during dry weather, sand would drift into the conduit, making it difficult to secure good contact between the shoe and the conductors. For these reasons it was found necessary to change to an overhead trolley system, which has been done during the present year.

As the authorities objected to having a trolley wire strung over the street by means of guy wires, because of the unsightliness of such a construction, it was necessary to suspend the wire by bracket supports. To have the wire over the middle of the track would in many places require very long brackets, so it was decided to use the side running trolley with long trolley poles. It is stated that little or no difficulty is experienced in keeping the trolley on the wire, but it should be added that the maximum speed does not exceed 10 miles per hour. It is very doubtful if the device would work on many of our American roads, where speeds exceeding 30 miles per hour are attained. It may also be questioned whether the unsightliness of the overhead construction necessary to support a wire over the middle of the track, is not to a large extent offset by the ugliness of the car in the present case, although the latter may be partly due to the glaring advertisements with which it is so profusely plastered.

It is worthy of note that power is supplied to this line from generators direct-connected to Parsons turbines, there being two units of 200-HP. each.

For the information from which this article has been prepared we are indebted to the London "Electrician," and for the photographs to Messrs. Lowdon Bros. & Co., of Edinburgh, who were the contractors for the overhead work.

FIG. 1.—ELECTRIC RAILWAY LINE AT BLACKPOOL, ENG.
Lowdon Bros. & Co., Edinburgh, Contractors.

FIG. 2.—CARS EQUIPPED WITH SIDE-RUNNING TROLLEY, BLACKPOOL ELECTRIC RAILWAY.

A FAST RUN between New York and Buffalo was made by the special newspaper train of the Delaware, Lackawanna & Western R. R., on Sept. 17. The distance of 410 miles was covered in the actual running time of 7 hrs. 23 mins. It is stated that at times a speed of 80 miles per hour was attained.

ABSTRACTS OF PAPERS READ AT THE CONVENTION OF THE CENTRAL STATES WATER-WORKS ASSOCIATION.

"Municipal Ownership of Water-Works."

By Jos. J. Pater, Hamilton, O.

The author stated that he represented the city of Hamilton, which controls its own water-works, gas-works and electric light plant. An unlimited supply of pure water is necessary to health. The citizens will demand it, and even the politicians cannot disregard public opinion. Referring to the Cincinnati water-works, he suggested that no private corporation would expend $6,000,000, as the city is now doing, to secure an abundant supply of pure filtered water. A municipality will conduct its water-works for the benefit of the community; a private corporation, to increase the profits of its stockholders, paying little regard to public health or its demands.

He next discussed the subject of electrolysis and the damage which is being done to water mains, because of it. "If this matter is not thoroughly investigated by competent electricians, and a remedy found where the single trolley is in vogue, much damage will be done, and in a few years many miles of water mains will have to be replaced. Municipalities, as well as private corporations, are entitled to protection from the destruction of their property. Some damage is being done in Hamilton; and Dayton, which has made a thorough investigation of the subject; has found its water mains alone, not including private services, damaged to the extent of nearly $30,000, and has brought suit against the railway company to recover. Indianapolis refused, after a careful investigation, to purchase the water-works owned by a private company on account of the damage to the mains from electrolysis. The water mains in Cincinnati have not been affected, as the double trolley system has prevented it. A municipality should not recommend an experimental remedy, but should compel, by litigation, if necessary, the street railway companies of the single trolley system, using the rails to complete their circuit, to protect the water and gas-mains from destruction."

The speaker next took up the subject of water meters, remarking that they were absolutely essential to conduct a water-works on business principles, as well as saving water to consumers; that they preserve the pressure and give good fire protection by preventing waste; also that the expense of the water department is thus reduced without reducing the proper supply of water. He was of the opinion that the public should be encouraged to use water freely for all purposes, the meters preventing waste. Friction between officials and consumers is also reduced. Figures from over 100 cities show that those which have metered all consumers pump only one-half as much water to supply the demand as those which have the flat rate system. Large cities find this an enormous saving to the water department. "Meter every customer of water, the same as gas, and a great reduction in expense will be noticed at once."

"Application of Compressed Air for Supplying Water."

By C. W. Wiles, Delaware, O.

Mr. Wiles discussed the subject of air lifts and air compressors, and their application to water-works requirements, and said in part:

The system of supplying water from deep wells by an air lift or air compressor, is one not in general use in this country and has to some extent been an experiment. Results, however, have justified the opinion that for moderately flowing wells, or wells having a head of not more than 25 or 30 feet below the surface, being too low to draw from by ordinary suction pumps, the application of compressed air at some distance below the top has largely increased the supply of water.

Papers were read on "Electrolysis," by Mr. J. H. Schaffer, Cincinnati, O., and Mr. F. A. W. Davis, Indianapolis, Ind., and a committee consisting of the two just named and Messrs. Chas. E. Rowe, Dayton, O., and C. W. Wiles, Delaware, O., was appointed by Pres. Thos. J. Cook, with Mr. Davis as chairman, to secure information on the subject of electrolysis and report at the next annual convention.

"The Sanitary and Chemical Purification of Water Due to Softening."

By N. O. Goldsmith, Cincinnati, O.

This speaker claimed that the removal of the soluble lime salts, which are the cause of hardness in water, is accompanied by the same bacterial purification as is obtained by the use of sulphate of alumina as a precipitant. A double purification is thus secured. Mr. Goldsmith showed the advantages of soft water, and that it is more economical for both domestic and manufacturing purposes, saving soap, the wear and tear of clothing, and in the keeping of boilers and steam heating apparatus free from the lime deposits which form when hard water is used.

CIVIL SERVICE EXAMINATIONS for positions in the Department of Public Improvements of New York city will be held as follows: Sept. 26, mechanical draftsman; Sept. 26, levelers; Oct. 2, axeman; Oct. 3, district superintendent department of street cleaning; Oct. 9, assistant engineer. Lee Phillips, Secretary, Municipal Civil Service Commission, New York, N. Y.

CONCRETE-STEEL BRIDGE CONSTRUCTION.

(With full-page plate.)

By Edwin Thacher, M. Am. Soc. C. E.*

A concrete-steel structure is a combination of concrete and steel in which steel in any form is rigidly imbedded in concrete, the concrete stiffening the steel, and the steel reinforcing the concrete.

As the concrete and steel have a continuous adhesive connection, and have practically the same coefficient of expansion, the relative stress borne by each will be in direct ratio to their moduli of elasticity and inversely as their moments of inertia.

As in all combinations of concrete and steel, the stress is governed by the moduli of elasticity, it is not practicable, however, much it may be desired, so to design a structure that each material will have a stress in proportion to its ultimate or elastic strength, and the consequence is that the steel has a stress under normal conditions far below its safe limit. Combinations are often made for beams and girders in floor construction, in which the steel is designed to sustain the entire load, including the concrete, and in which the steel is subjected to a high stress, but even in this case the two materials will act together until the ultimate tensile resistance of the concrete is reached, and if cracks afterwards develop they will not endanger the safety of the combination.

The amount of steel to be used in concrete steel arches, must be sufficient to keep the tensile stresses in the concrete within safe limits, and the writer makes the further provisions that the steel must be capable within its elastic limit of taking the entire bending moment of the arch without aid from the concrete, and have a flange area of not less than 1-150th part of the total area of the arch at the crown. Though the steel can never take the entire bending moment under normal conditions, it is a comfort to an engineer to be assured that if through the carelessness or dishonesty of a contractor, or incompetency or connivance of an inspector, any part of the concrete should be of poor quality, or the specifications as to continuous work be disregarded, his work will still continue to stand and do its duty.

In 1890 the Austrian Society of Engineers and Architects appointed a committee to undertake a comprehensive series of experiments on arches of various materials, and the report of the committee made in 1895 is the most valuable contribution to the theory and practice of arch construction that has ever been made. The tests were carefully made, and were superintended and discussed by competent engineers. Numerous experiments were made on arches of brick, stone, concrete, concrete steel, corrugated plate, and steel, for spans of 4.43, 8.86, 13.3, 32.8 and 74.5 ft. The results of these experiments have been published in various engineering papers and will not be repeated here. The conclusions, however, have an important bearing on the calculation of concrete steel arches. For all the arches it is shown that the theory of elasticity gives the only solid foundation for theoretical investigation, since deformations were practically proportional to the stress in all cases where the elastic limits were not exceeded. This view, even when applied to stone arches, has been accepted by the majority of our best authorities on the subject in this country, and there can be no question of its correctness when applied to a monolithic elastic concrete steel arch.

Calculations for thrusts, bending moments, and shears, can be made graphically or analytically, but unless the arch is segmental, or parabolic, and the sections nearly uniform, the writer considers analytical investigations too complicated and laborious to be considered, as a busy calculator has no time, even though he may have the ability to reduce integral equations to the proper form to be used in any special case. An economical concrete steel arch is usually neither a segment nor a parabola, and the moment of inertia at the end is frequently 30 times as great as at the center, which is very important to consider. Reliable graphical methods have been developed, applicable to any section or form of arch, by which thrusts, bending moments and shears are quickly found. The work checks itself; the faults in design, if any, are visible to the eye, and can be corrected; there is no danger of misplacing a decimal point, which often results from hair-splitting calculations, and the results, the writer believes, are more reliable and satisfying than it is possible, or at least practicable, to get by analytical methods.

In late designs for concrete steel arches, the writer has endeavored to have the line of pressure lie within the middle third of the arch ring, and have no tension on the concrete from dead or live load. By a due amount of patience this can usually be done, not only as regards dead and live loads, but temperature stresses as well. The writer, however, has never succeeded in doing this economically with a segmental arch. He prefers and generally uses with solid spandrel filling a three-centered arch, as it is less troublesome to construct, and, he thinks, is more pleasing to the eye than a five-centered or elliptical arch, though the latter will frequently take less material.

Arches with solid spandrel filling should be flat at the center, and sharper at the ends, approaching an ellipse; while arches with open spandrel spaces should be sharp at the center and flatter at the ends approaching a parabola, or, which is better, sharp at the ends and center and flat at the haunches. Having found the thrusts, bending moments and shears, the following formulas deduced by the writer for distribution of material will apply to any form or variety of concrete-steel arch or beam, within the limits of elasticity of concrete:

E_1 = modulus of elasticity of concrete, = 1,400,000 lbs.; E_2 = modulus of elasticity of steel, = 28,000,000 lbs.; A = area of steel rib, in sq. inches; A_1 = area of section of concrete 1 inch wide; A_2 = area of steel rib ÷ b; I_1 = moment of inertia of A_1, about common neutral axis; I_2 = moment of inertia of A_2, about common natural axis; S_1 = stress per sq. in on concrete, in lbs.; S_2 = stress per sq. inch on steel, in lbs.; d_1 = depth of concrete, in inches; d_2 = depth of steel, in inches; t_1 = distance from center of gravity of combination to outside of concrete, in inches; t_2 = distance from center of gravity of combination to outside of steel, in inches; T = thrust on section of arch 1 in. wide, in lbs.; M = bending moment on section 1 inch wide, in ft.-lbs.; P = pressure on line of pressure for strip 1 in. wide; e = distance from center of gravity of combination to line of pressure, in inches; c = distance from center of gravity of steel rib to bottom of concrete, in inches; b = distance from c. to c. of steel ribs, in inches.

For symmetrical sections,

$$S_1 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{6\,d_1\,M}{(I_1 + 20\,I_2)}\right]. \quad (1)$$

$$S_2 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{6\,d_2\,M}{(I_1 + 20\,I_2)}\right] \times 20. \quad (2)$$

For unsymmetrical sections,

$$S_1 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{P\,e\,t_1}{(I_1 + 20\,I_2)}\right] \quad (3)$$

or

$$S_1 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{12\,m\,t_1}{(I_1 + 20\,I_2)}\right]. \quad (4)$$

$$S_2 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{P\,e\,t_2}{(I_1 + 20\,I_2)}\right] \times 20 \quad (5)$$

or

$$S_2 = \left[\frac{T}{(A_1 + 20\,A_2)} \pm \frac{12\,m\,t_2}{(I_1 + 20\,I_2)}\right] \times 20. \quad (6)$$

Distance from bottom of concrete to center of gravity comb,

$$= \left[\frac{A_1\,d_1}{2} + 20\,A_2\,c\right] \div (A_1 + 20\,A_2). \quad (7)$$

To satisfy the condition that the steel shall be capable of taking the entire bending moment without exceeding its elastic limit, taking the elastic limit of steel at 36,000 lbs.

$$I_2 > = \frac{M\,t_2}{3{,}000}. \quad (8)$$

For symmetrical sections, and when each rib consists of two bars as in the writer's patented system,

$$A_2 > = \frac{M}{1{,}500\,d_2}. \quad (9) \quad \text{or,} \quad A > = \frac{M\,b}{1{,}500\,d_2}. \quad (10)$$

also make

$$A > = \frac{d_1\,b}{150}. \quad (11)$$

d being the depth of concrete at crown.

Symmetrical sections are those in which the centers of gravity of the concrete and steel coincide, in which case formulas 1 and 2 apply, but it is sometimes necessary, particularly in the Melan system, to use unsymmetrical sections, or such that the centers of gravity of the concrete and steel do not coincide, in which case formulas 3 and 5 or 4 and 6 are used.

The formulas consider that when used in large masses the modulus of elasticity of steel is 28,000,000 lbs. and the modulus of elasticity of concrete 1,400,000 lbs. or that one is 20 times as great as the other. The Austrian Society of Engineers and Architects made a large number of experiments on the materials used in the arches tested, and the above values are, in round numbers, the result of such experiments on the 74.5-ft. spans, which are much lower than the mean values found on small specimens, which ranged from 29,700,000 to 31,400,000 for steel, and from 1,400,000 to 4,000,000 for concrete, and from 5,000,000 to 6,000,000 for 1 to 3 mortar.

Experiments made by Prof. C. Bach, of Stuttgart, in 1894, on concrete cylinders, 9.84 ins. diam. and 3.28 ft. long, showed that any concrete when subjected to stress has a permanent set and an elastic deformation, which becomes constant after several repetitions of the same stress, and up to about 0.7 the breaking stress, which was regarded as the natural limit of allowable stress. The modulus of elasticity at 500 lbs. per sq. in. ranged from 2,430,000 to 3,840,000 and the modulus of permanent set from 9,000,000 to 32,500,000.

Elasticity.—The elasticity of concrete is well illustrated in a test made by the Austrian Society on a concrete arch 32.8 ft. span, and 3.28 ft. rise, and 7.87 ins. thick at crown, which showed no signs of failure when one-half the span was loaded with 2,110 lbs. per sq. ft., although the deflection was over 11 ins. Mr. Ransome experimented on a reinforced concrete beam 11.0 ft. long, and 11¼ ins. deep. It was loaded to deflect 15-16-in. and gave no signs of failure or even hair cracks, and on removing the load the beam showed a permanent set of only ⅜-in.

The theory of concrete steel construction considers that concrete and steel have practically the same coefficient of expansion, and strong adhesion, and durability demands that the imbedded steel shall be permanently protected from oxidation.

Expansion.—Benniceau, a French author, gives the thermic expansion of Portland cement as .0000143 Celsius, while iron has .0000145 practically the same. Mr. Thaddeus Hyatt, in a book published in London in 1877, proves the extension of concrete and steel to be equal, whether under load or fire, and concludes that the two materials may be regarded as practically homogeneous.

Adhesion.—Prof. Bauschinger found the adhesion between iron and concrete to be from 570 to 640 lbs. per sq. in., which is more than the tensile strength of the best concrete. The Monier Co. experimented with a wire 9-32-in. in diameter, imbedded in a baluster which had been exposed to the weather for ten years. An attempt to pull the wire from the concrete resulted in its rupture under a strain 2,860 lbs. The great adhesion is attributed to a chemical connection between the silicates of the cement and steel. A bridge floor in Lincoln Park, Chicago, has steel wires imbedded in concrete composed of 1 part cement, 2 parts sand, and 4 parts blast furnace slag. Two experiments were made on No. 8 galvanized wire imbedded in a 6-in. cube of concrete. The wires were straight and passed entirely through the blocks. No special care was taken in making the blocks, they were kept in a dry basement and tested at an age of three months. The adhesion was found to be 65 lbs. and 67.5 lbs., respectively, per lin. in., or 130 lbs. to 135 lbs. per sq. in. This low result as compared to the preceding examples may have been due to the galvanizing of the wire, the slag of the cement, the want of care in making the tests, or most probably the writer believes from want of water necessary for proper chemical action. After concretes have partially set they should be given all the water they will absorb. When they have had enough they will refuse to take more. Rich facing mortar if not kept wet for some days after placing will be weak and brittle, and can be easily crumbled between the fingers. Although the natural

*Savings Institution Building, Paterson, N. J.

adhesion between concrete and steel appears to be very great, the writer does not consider it wise to place entire reliance upon this in concrete steel construction, but provides mechanical connection sufficient to insure its safety in case the adhesion from any cause amounts to little or nothing.

Concrete as a Preservative of Iron and Steel.—Fr. Von Emperger, Member Austrian Society of Engineers and Architects, states that he knows of a case where iron rods were found perfectly rust free, having been imbedded in concrete below water level for 400 years. W. G. Triest, Jun. Am. Soc. C. E., states that the cast-iron concrete-filled pillars of a viaduct were taken down in 1893, and a wrench was found rust free that had been imbedded in the concrete for 22 years. The Monier Co., in Germany, found that a wire imbedded in a concrete plate which had been immersed in water for months, not only did not exhibit signs of rust, but retained its original blue color; while in another plate the protruding ends of wires 9-32-in. and 13-32-in. in diameter, were entirely eaten away, and the covered portions were unaffected. Ernest L. Ransome states that a long time ago he imbedded a dozen pieces of hoop iron in as many blocks of concrete, leaving one end of each piece of iron projecting from the surface; after years of exposure to sea air all the exposed iron had rusted away, or so nearly as to leave but a few soft jagged needles of rust that were readily removed by the hand. In all cases upon cutting into the blocks one or two inches the iron was rust free.

Allowed Tension in Concrete.—The 74.5-ft. span concrete arch tested by the Austrian Society led to the conclusion that the ultimate tensile strength of concrete was 290 lbs. per sq. in. Mr. Von Emperger quotes* Prof. Engesser as recommending a working stress of 213 lbs. per sq. in.; Mr. A. Rolla as recommending a working stress of 125 lbs. per sq. in.; and Mr. J. Melan as recommending a working stress of 60 lbs. per sq. in. Keepers & Thacher, in the specifications appended, allow a working stress of 50 lbs. per sq. in. The reason given for allowing such high working stresses, and which leads Mr. Von Emperger to say that 60 lbs. is certainly too small, is that a concrete beam, after passing the elastic limit, shifts the neutral axis, and breaks under about double the theoretically-calculated breaking load. This reason may be good, but there is no question that within the elastic limits the beam theory is correct, and the writer believes it better to base his calculations on what happens within those limits, than to go to the breaking-point where he does not wish his structure to follow.

Hinged Arches.—It has become quite customary of late in Europe to hinge arches of stone and concrete at the crown and springing line. Hinges have sometimes been made to admit of a rotary movement, though the friction due to the intense pressure at the hinges would undoubtedly prevent any actual rotation at those points, and sometimes contracted flat bearings have been provided. These hinges or bearings have been made of granite, sandstone, cast-iron, steel, lead, and asphaltum; the object being to confine the line of pressure within fixed limits, and to prevent cracks in the arch by unequal settlement of foundations. The hinges undoubtedly accomplish their object to a great extent, but it is nevertheless a question whether the advantages of such construction are not outweighed by the disadvantages. Arches with hinges have greater deflection and vibration; they are inferior from an aesthetic point of view; they really admit of no greater accuracy of calculation than the fixed arch by the elastic theory, which has been verified by the experiments of the Austrian Society; they are no more economical, all things considered; and the appearance of solidity, rigidity and durability, so pleasing in a fixed arch, is to a great extent wanting in a hinged structure, unless the hinges can be hidden from view. As stone arches frequently crack, it becomes a question whether a hinge or a crack is most unsightly, and the writer believes that the use of hinges in stone arches may sometimes be advisable, and to a lesser extent in concrete arches, but as a concrete steel arch has never been known to crack to the writer's knowledge, there will be time enough to consider hinging them after the first crack appears.

The Topeka bridge, consisting of one span of 125 ft., two spans of 110 ft., and two spans of 97.5 ft., was erected on pile foundations in soft sand. It has passed through extremes of heat and cold, and has settled at least all it will, and no signs of a crack appear in any of the arches. Although concrete steel arches do not crack, the spandrels sometimes do, and the reason for it we do not have to go far to find, nor is it difficult to provide a remedy. If the centering is lowered before the fill is put on, and after the spandrels are built, the arch is in the condition of a bent strut and will rise at the haunches, which is liable to crack the spandrels at or near the points of contraflexure. If the centering is lowered before the spandrels are built, the spandrels will not crack, but the addition of the fill has a tendency to separate the arch from the spandrel. This has sometimes happened, though not on any work with which the writer has been connected. The best and safest way is to complete the fill before the centers are lowered, and under such conditions the writer has never known any cracks to appear in the spandrels. This cannot always be done without considerable delay and extra expense, as in bridges with duplicate spans it is desirable to use the same centering for more than one span, and the placing of the fill will usually seriously interfere with the work of concreting if carried on at the same time, so to provide for all cases that can happen, the writer has in late designs inserted steel bars in the spandrels, which he believes will prevent any future trouble, even though the centering is removed before the fill is put in.

The following information relating to the Topeka bridge that has not appeared in any of the published accounts, will probably be of interest to engineers. The settlement of the centerings, from the time the concreting was commenced until it was completed, ranged from 5-16-in. to ½-in. for the different spans, most of it being due undoubtedly to the closing-up of the joints of the centerings and bringing them to bearing. The settlement on removing the centering ranged from 3-16-in. to 5-16-in. for the different spans, the centering being removed in about 28 days after the completion of the arches. Compared with the settlement of 4.88 ins. to 5.39 ins. in the Munderkinger hinged arch of 164 ft. span this appears insignificant.

The bed of the river at low water at the bridge site is about one-half sand bar and the other half has from 1 ft. to 4 ft. of water. The original profile on which the design was made showed a few feet of soft sand, then compact sand, and finally hard cemented sand, the latter being on an average 16 ft. below low water. The excavation in all cases was designed to enter this hard material. When the coffer dams were completed and the excavations made, this hard material failed to materialize at any of the foundations, but was soft sand with an occasional streak of clay all the way down. There were, however, plenty of piles to carry the load, and the foundations were carried only to the depths designed. The south abutment was located in the deepest part of the river channel, and the sand back of it scoured out about 16 ft. below low water, or nearly to the bottom of the concrete foundation. The fill back of this abutment had been carried up a little above low water, when it became desirable to use the centering for the south span at the north end, and the writer considered it risky to let the thrust of the 97.5-ft. span come upon this abutment founded in soft sand and with no fill back of it, for if the abutment took a notion to rotate the result would have been disastrous. He therefore designed, and the Superintendent and County Commissioners approved and ordered, an addition to both abutments, consisting of a layer of 21 ins. of concrete doweled to the back of the original abutment, and extending down to low water. In this new concrete was imbedded steel bars 8 ins. by 11-16-in., securely connected to the top flange of each steel rib of the arch. Moments were taken about a point in the center of the foundation, 28.5 ft. below the springing line, and 16 ft. below low water, and the moment of the working stress of the bars was made equal to the algebraic sum of the overturning moments, resulting in practically hinging the abutment at the bottom of the foundation, and converting rotation into translation. After these additions were made the centering was removed before any further fill was made. No measurable movement of the abutment took place, and no cracks appeared in arch or abutment. Although the same necessity for strengthening did not arise at the north abutment it was considered best on account of the soft foundation and small cost to make the same additions there.

Concrete Piers.

Concrete piers for railway and highway bridges are now being built quite extensively in this country, and many engineers prefer them to any except the most durable stone. C. D. Purdon, Assistant Chief Engineer, A. T. & S. F. Ry., speaks as follows of the concrete piers for Red River bridge (St. Louis & San Francisco Ry.), built by him:

> I had an opportunity of inspecting them after a most extraordinary flood, caused by a water-spout in which the river rose 1.4 ft. above the highest water known, the current being estimated at eight or nine miles an hour, and very large quantities of drift running. Among the drift were cottonwood trees 2 ft. to 3 ft. in diameter, many of which I am informed were broken on the piers from the force of the current. No damage whatever was done to the piers, and no greater marks left by drift than could be made by a stick held in the hand and dragged across the surface. It is the opinion of the bridge inspectors of the St. Louis & San Francisco Ry., who watched the bridge during the flood, and who are men of considerable experience, that had the piers been built of masonry of such stone as could have been obtained, that they would not have been able to withstand the drift, and the bridge would have been destroyed.

Mr. Geo. H. Pegram, Chief Engineer, Manhattan Elevated Ry., and formerly Chief Engineer of the Union Pacific Ry., has had a large experience with concrete piers, and speaks of them in the highest terms. The bridge across the Arkansas River, at Main St., Little Rock, built under the direction of the writer, has concrete piers. The piers are from 35 ft. to 71 ft. high, and carry spans from 140 ft. to 374 ft. in length, and are giving perfect satisfaction.

Concrete Arches.

The conclusion drawn from tests on the 4.43-ft. and 8.86-ft. span floor arches by the Austrian Society, was that arches 3 ins. thick, made of 1 part Portland cement and 5 parts sand, have about the same strength as brick arches 6 ins. thick, and less than one-half the deformation. Concrete arches built by the Romans more than 2,000 years ago are still standing in a very good state of preservation, although the cement used was much inferior to the Portland cement of the present day, and the stone used was of much larger size than is commonly used now, giving a less homogeneous structure. The following notable concrete bridges have been built in Europe during the past six years:

The bridge over the Danube at Munderkingen, Germany, built in 1893, has a span of 164 ft. and a rise of 16.4 ft., and has three steel hinges. The arch is built of 1, 2½ and 5 concrete, deposited in blocks as voussoirs from 3.25 ft. to 5 ft. long, measured on the intrados, and is not a perfect monolithic mass. The centers were struck in 28 days after the completion of the arch, and the settlement at crown was 4.88 ins. and 5.39 ins. on the two faces, respectively, or 5.13 ins. average.

The Coulouvreniere bridge over the Rhine, at Geneva, Switzerland, built in 1895, has two spans of 131.2 ft. each, 18.2 ft. rise, with a small span between them. The large arches have three steel hinges, and the concrete was deposited in voussoirs measuring 3.28 ft. in the intrados, the construction in all important particulars being the same as at Munderkingen. The centers for both arches were struck in about 2½ months after their completion, and the average settlement at the crown was 1.02 ins., which increased to a final settlement of 1.57 ins.

The bridge over the Danube at Inzigkofen, Germany, built in 1895, has a span of 141 ft. and a rise of 14.4 ft., and has three cast-iron hinges. The concrete used was 1, 3 and 4 in the arch; 1, 3 and 6 in the foundations, and 1, 4 and 8 in the abutments. The concrete in the arch was deposited in sections, or voussoirs, from 3.3 ft. to 4.3 ft. long. The center was struck five weeks after closing the arch, and the settlement was about 1.25 ins.

The bridge over the Eyach, near Imnau, Hohenzollern, built in 1896, has a span of 98.45 ft. and a

*Trans. Am. Soc. C. E., April, 1894.

rise of 9.84 ft., and has three granite hinges or blocks 1.64 ft. deep, with 4 ins. contact surface, covered with 3-16-in. lead plates. The concrete used was 1, 2½ and 5 in the arch, and 1, 3 and 6 in the foundations. On removing the centering the settlement at crown was 19-32-in., gradually increasing to 1 3-16 ins. in 11 days.

A bridge over the Thames, at Vauxhall, London, is now in process of construction, and consists of two spans of 130.56 ft. and 144.56 ft., respectively, of three hinged concrete arches. All exposed surfaces except the arch soffits have a face of white granite. The concrete used is 1 and 4 in the arch; 1 and 6 in the piers, abutments and spandrels, and 1 and 8 in the foundations.

Concrete Steel Structures.

Mr. Geo. S. Morison, M. Am. Soc. C. E., says: "I fully believe that we are now only at the beginning of concrete construction, and that if the results we hope for can be obtained with concrete structures, with metal structures inside, the time will come when this will be the one method of building." The writer fully indorses this opinion. The advantages of concrete-steel arches do not lie so much in the direction of diminished sections and cost, as compared with the use of concrete alone—as the writer does not approve of paper-like dimensions, nor of designs which would not be reasonably safe with the steel left out—but in the vastly increased security which the steel affords in providing against shrinkage, settlement, or other conditions which cannot be calculated or foreseen with any degree of accuracy. The steel in this case acts as a powerful reserve force, comparatively at rest so long as the concrete is able to do its share of the work, but ready to step in and do it all if necessary in case of emergency; or, to illustrate this point more clearly, the specifications following, limit the tension in concrete under calculated conditions to 50 lbs. per sq. in., and by careful design this is frequently reduced to 0, and as the moduli of elasticity of concrete and steel are as 1 to 20, the maximum tension in the steel under calculated conditions cannot exceed 20 × 50, or 1,000 lbs. per sq. in. It will be readily seen, therefore, that the steel holds in readiness a reserve force of about 35,000 lbs. per sq. in. before its elastic limit will have been reached, and before any visible cracks will appear in the concrete.

Concrete iron beams have been used in the United States, France, and England in one form or another for the past 40 years, but the first concrete metal arch was invented by Jean Monier, of France, in 1876, and is known as the Monier system. It consists of wire nettings imbedded in concrete. Originally one netting was used near the intrados of the arch, but two nettings were afterwards found necessary, particularly in large spans. Many Monier arches have been built in Europe, particularly in Germany, Austria, France and Switzerland, and tests made on them by the Austrian Society of Engineers and Architects, show their superiority over stone, brick, or concrete alone, but they have practical disadvantages which cannot be overcome. The transverse wires of the nets take no strain, and could be about as well omitted, and the nets are so flexible and unruly that it has been found impracticable to imbed them in concrete containing coarse aggregates like gravel and broken stone, the consequence is that all Monier arches up to this time have been built with 1 and 3 mortar, which, as compared with, say, 1, 2½ and 5 concrete, is weaker and costs 50% more. Many bridges have been built on the Monier system with exceedingly delicate dimensions; three built in Switzerland in 1891 have 128-ft. span, and 11-ft. rise, the arches having a thickness of 6⅔ ins. at the crown and 10 ins. at the abutments. One built in Germany in 1890 has 132 ft. span, 14.66 ft. rise, and the arch has a thickness of 9.88 ins. at the crown. A Monier arch 32.8 ft. span, 3.28 ft. rise, 13.2 ft. wide, 6 ins. thick at crown, and 8 ins. thick at abutments, was tested for the Southern Railway of Austria in 1890, as follows: First, 40-ton locomotive on crown; second, 53-ton locomotive over half the arch; third, 1,000 lbs. per sq. ft. on half-span; fourth, 1,700 lbs. per sq. ft. on half-span, at which the abutments gave way. At 2,000 lbs. per sq. ft. the arch sank without entirely breaking.

The concrete metal arch known as the Wunsch system was invented by R. Wunsch, of Hungary, in 1884. It consists of an arched lower, and straight upper member of metal imbedded in concrete, and connected with vertical members imbedded deeply in the piers and abutments. Six spans of this system, the longest being 55.66 ft., have been built in Hungary, and tests made by the Hungarian government were satisfactory.

The concrete metal arch known as the Melan system, was invented by Joseph Melan, of Austria Hungary, in 1892, and was patented in the United States in 1893. It consists of abutments, beams or girders; arched ribs rigidly connected with said abutments, beams or girders; and a filling of concrete or the like between said ribs. Experiments made by the Austrian Society on a 13.3-ft. span, 0.94-ft. rise, and 3.15-in. thick, gave highly satisfactory results. After being loaded with 1,500 lbs. per sq. ft. the pig-iron ran out, and a square of 10 sq. ft. was then loaded with 3,000 lbs. per sq. ft., and the arch broke under 3,360 lbs. per sq. ft. Mr. Von Emperger mentions the following bridges on this system built in Europe: One span of 23.6 ft. at Naustadt, Silesia; one span of 39.4 ft. at Oderberg, and six spans of 65.6 ft. each at Rostock. Mr. Albert W. Buel, in the "Polytechnic," of March, 1899, gives a complete list of the Melan bridges built in the United States up to date. The list covers 27 bridges, and 34 spans. The most important are the five-span bridge at Topeka, Kansas, and the three-span bridge at Paterson, N. J., both of which were designed and built by Keepers & Thacher, and which, together with most of the others, have been fully described in the Engineering Journals.*

A concrete-steel bridge designed by the writer, and patented Jan. 10, 1899, and which, by way of distinction, will be called the Thacher system, may be described as follows: Steel bars in pairs, spaced at proper distances apart, and spliced at convenient intervals, are imbedded in the concrete near the outer and inner surfaces of the arch, and extend well into the abutments or piers. The bars of each pair have no connection with each other, except through the concrete, but each bar is provided with projections, preferably rivet heads of extra height, but which may be lugs, dowels, or bolts, spaced at short intervals, thereby providing a mechanical reinforcement of the adhesion between the steel and the concrete, so that a complete crushing or shearing of the concrete must take place before a separation can be effected. The bars act as the flanges of a beam to assist the concrete in resisting the thrusts and bending moments to which the arch is subjected. The shearing stresses are small, and the concrete is amply able to take them many times over. The principal advantages which this system offers over those previously mentioned may be stated as follows:

It gives a larger moment of inertia, and consequently greater strength for the same amount of steel. In the Melan system I-beams are usually used, which, if buried in the concrete, are necessarily less in depth throughout, than the depth of arch at crown, and as the depth of arch at spring is usually about three times the depth at crown, and the greatest bending moments are always at or near the spring, the use of I-beams gives the least strength, and reserve of strength, where the greatest is needed. If the beam is made of angles with lattice connections, as at Topeka, it is not practicable even then to follow throughout the lines of greatest strength, as the beams become too deep and unwieldy.

A more reliable connection is secured between the steel and the concrete than in any system that depends on adhesion alone.

The bars can be shipped straight in any convenient length, and bent cold to any desired curve resulting in less cost for manufacture and greater convenience in handling and shipping.

The following bridges have been built on this system: A bridge at Albion, Mich., of three spans, each 46.67 ft. clear, with a rise of 6.33 ft. This bridge has a 21-ft. roadway, and one 6-ft. 8-in. sidewalk. All exposed surfaces except the underside of the arch are faced with limestone. Fig. 1 shows this bridge after completion, and Fig. 2 during construction. A bridge at Tecumseh, Mich., one span 25 ft. clear, with a rise of 8 ft. 1 in. This bridge has a 21-ft. roadway, and one 5-ft. sidewalk, and is faced with stone. Fig. 3 shows this bridge after completion, and Fig. 4, during construction. A bridge over Beargrass Creek, at Kentucky St., Louisville, Ky., one span 50 ft. clear, with a rise of 11 ft. 2 ins. This bridge has a 36-ft. roadway, two 10.5-ft. sidewalks, and carries a 48-in. water-main weighing 1,600 lbs. per lin. ft., supported by stirrups, and distributed by cross beams over a section of arch 8 ft. in width. This increased load did not add to the sections of the arch, but actually improved its condition. This bridge has a concrete face, marked to represent ashlar masonry. Owing to the delay of the city authorities in building the approaches, this bridge remains in an unfinished condition. The earth fill, pavements, and removal of centering yet remaining to be done, but the contractors hope to have it completed during the present century. Fig. 5 is a view of this bridge. All of the above bridges have given complete satisfaction.

An improvement in concrete steel bridges, applicable also to concrete, brick or stone bridges, made by the writer and patented in 1896, can be used with great economy for long-span arches, and for spans of moderate length when the location admits of a rise of ⅛ of span and upwards. The improvement consists in the use of steel posts or bents in the spandrel spaces, in place of earth filling, or masonry walls and arches usually employed, and has the following advantages:

(1) The loads and stresses sustained by the arches, piers, abutments and foundations are much reduced.

(2) The spandrel face walls, if used, are relieved from all thrust or pressure, and hence may be greatly reduced in thickness, weight, and cost, and the bents will support the spandrel face walls instead of the walls being required to support the filling, as is usual.

(3) The arch and spandrel face walls are open to inspection inside and out, hence defects, if any, can more readily be found and remedied.

(4) The spandrel spaces can be kept dry, protecting the outer faces from discolorations and blemishes due to earth and moisture.

(5) There is no danger of the settlement of roadway.

(6) If thought desirable, the spandrel walls can be omitted, and the bents inclosed in a veneering of concrete.

The bents are connected by concrete arches just below the grade line, furnishing a foundation for a pavement of brick, stone, asphalt, or any other kind desired. The spandrel spaces can be utilized if desired for storage or other purposes, and light and ventilation can be provided. The steel bents, if not enclosed, should be given two or three coats of Portland cement grout, which will preserve them for all time. A design for a bridge, as above described, made for St. Pierre Hollow, Schenley Park, Pittsburg, Pa., in 1896, is shown by Fig. 6. The stone arch finally adopted and built at this place was described in Engineering News of June 22, 1899. A similar design, made for Junction Hollow, Schenley Park, has a central clear span of 300 ft., with rise of 66 ft. 2 ins., flanked by 70-ft. and 61-ft. spans, and has a width of 80 ft. between parapets. The central arch ring has a depth of 48 ins. at the crown. The pressure on the arch and foundations is less than one-half the amount that would be produced by the usual construction. Keepers' & Thacher's bid on this bridge, 590 ft. long, and covering 47,200 sq. ft. in clear between stone parapets, erected and paved complete, ready for traffic, was about $7 per sq. ft., only a trifle more than was paid for the steel arch which was accepted and built, in this locality so admirably fitted by nature for a grand record-breaking arch that would command the admiration of the world for ages to come.

*The following is a list of the most important articles on concrete, and concrete and steel bridge construction which have appeared in Engineering News, Vols. XXIII. to XLI., 1890 to 1899, inclusive: January-June, 1893, pps. 148, 266; July-December, 1893, pp. 79, 157, 170, 189, 391; January-June, 1894, p. 305; July-December, 1894, pp. 28, 333, 439, 500; January-June, 1895, pp. 112, 247, 306; July-December, 1895, pp. 214, 306, 384; January-June, 1896, pp. 82, 100, 220, 238; July-December, 1896, pp. 32, 91, 122, 178; January-June, 1897, pp. 117, 496, 499; July-December, 1897, p. 205; January-June, 1898, pp. 99, 290; January-June, 1899, pp. 50, 94, 100, 175.

The writer can see nothing to prevent the building of concrete-steel arches with spans of 500 ft. or 600 ft. on this design, with unit stresses no greater, and safety no less than in spans of 100 ft. and under. Public confidence in concrete, and concrete-steel construction, is gaining rapidly in this country, and in Europe, where there is plenty of precedent, and where the people have been more thoroughly educated up to it, there has been no lack of confidence in it for some years. These engineers, who have used it the most, and investigated it most thoroughly, are its greatest admirers. We hear nothing now from intelligent men about mud bridges, and very little about thermal variations, indeterminate stresses, and the like.

Concrete-steel bridges, as compared with iron and steel structures, offer the following advantages: they are more beautiful and graceful in design, architectural ornamentation can be applied as sparingly or as lavishly as desired; they have vastly greater durability, and generally greater ultimate economy; they are comparatively free from vibration and noise; they are proof against tornadoes, high water or fire; the cost of maintenance is confined to the pavements, and is no greater than for any other part of the street; home labor is employed in building it, and the greater part of the money that it costs is left among the people who pay for it, and its cost as a rule does not much, if any, exceed that of a steel bridge carrying a pavement.

Materials and Workmanship.

The following matter has an important bearing on concrete-steel construction. Most of it has been selected from Engineering News, "Engineering Record," "Municipal Engineering," "Journal of the Western Society of Engineers," and "Trans. Am. Soc. C. E.," to which the writer desires to give due credit. Quotation marks have not been made as a rule, for in most cases the words of the author have been changed, and in all cases when his meaning could be expressed in fewer words, the idea being to present in a clear, brief, condensed form, properly classified for convenient reference, the governing facts relating to concrete construction and the experiments and opinions of many prominent engineers, experts and authorities, who have given the subject years of study and practical application, and when the opinions of engineers of equal eminence do not coincide, the reader must draw his own conclusions.

Portland Cement.—R. L. Humphrey, Inspector of Cements, Department of Public Works, Philadelphia, as a result of over 9,000 tests, from 38 brands of American, Belgian, Danish, English and German cements, shows the superiority of American cements.

Maj. W. L. Marshall, Corps of Engineers, U. S. A., says, if cements do not lose strength under long-time tests, then those cements that give the greatest strength in the shortest time, at least cost, with sand mixtures, are preferred by him, and truthfully adds, that as most work is subjected to its maximum stress within 30 or 60 days, that it matters little after it has failed for lack of strength, that it would have been adamant in strength in one, two or five years.

Sand cement, the invention of F. L. Smidth, of Copenhagen, is made by grinding Portland cement and sand together exceedingly fine, 95% passing through 180-mesh sieve, and is used in the same way as neat cement. It has been used extensively abroad, and to some extent in this country with satisfactory results. It is claimed that sand cement, composed of 1 part cement and 1 part sand, when mixed with sand for mortar and concrete, is superior to neat cement, that it has greater tensile and compressive strength, greater density and coherence, and is more easily worked with a trowel.

Fineness of grinding is very important. Experiments made by C. J. Wheeler, Chemist, gave the following result: (1) Briquettes made from screenings of cement that would not pass 200 sieve, and left in water 40 days, showed no signs of setting. (2) Briquettes made from cement containing 25% of residue on 200 sieve, gave after 7 days 666 lbs. neat, and 213 lbs. for 1 and 3 mortar. (3) Briquettes from fine cement that would all pass 200 sieve, gave after 7 days, 423 lbs. neat, and 366 lbs. for 1 and 3 mortar. The above tests show that the coarser particles are inert, and that neat cement tests have little value. Experiments made by David B. Butler, M. Inst. C. E., lead him to consider that the coarser particles are not inert, but have a certain value, approximately in inverse ratio to their diameter; also that extreme fine grinding decreases its cohesive power, but greatly increases its adhesive power, and value as cement, quickens its setting properties, and largely corrects any tendency to unsoundness. Fine grinding appears to be less important in natural than in Portland cement. Mr. Alfred Noble found that for Louisville cement fineness should depend on the amount of sand used. If 1 to 1, the presence of 20% of coarse particles, that will not pass 80 sieve, is not injurious; if 1 to 2, finely-ground cement is slightly better. This may or may not be true of other natural cements.

The Association of German Cement Manufacturers, after much discussion, agree that the addition of 3.5% of magnesia is not detrimental. Mr. Dyckerhoff states that 4% of magnesia, if sintered, has an injurious effect, producing increased expansion, and decreased strength after long periods, while actual cracking was observed with 8% magnesia.

Sand.—A. S. Cooper, U. S. Assistant Engineer, made numerous tests on briquettes with sand from 8-12 to 120-140 sieve, and found that as a rule, the coarser the sand the stronger the mortar, but the differences below the grades, 20-30, were so slight that they may be considered as one class.

Aggregates.—Mr. Dyckerhoff states that the addition of broken stone to a mixture of cement, sand and gravel, increases the strength; that 1 cement and 6 sand and gravel, with 8 broken stone, is at least as strong as the same mixture without the stone. Experiments made by Capt. Wm. M. Black, Corps of Engineers, U. S. A., on concrete of 1 and 2 Portland and natural cement mortars, mixed with gravel and broken stone, lead him to conclude that if concrete will be subjected to maximum stress during the first month, the aggregate should be stone alone when natural cement is used, and stone, or a mixture of stone and gravel, when Portland cement is used. With Portland cement, gravel alone may be used if the maximum stress is received after three months, and with natural cement, gravel alone may be used, if the maximum stress does not occur for a year. Mr. Ransome states that the hardest stone does not necessarily make the best aggregate; that finely-crushed granite is for some purposes inferior to finely-crushed limestone, or other softer rocks that have greater toughness and elasticity. Quartz and other stones having smooth surfaces are inferior to basaltic lava, sandstones, and the like, which have rough surfaces, as the adhesion of the cement is greater. Major Marshall shows by experiments that an admixture of not much exceeding 10% of the weight of cement, of limestone dust, does not reduce the strength of cement mortar, but seems rather to increase tensile strength, and he considers it a question whether crushed limestone should be screened at all for concrete. Mr. E. L. Ransome also says that if you are crushing clean stone, all the dust that you remove and replace by sand is to the detriment of the concrete; that experiments made here and in England show conclusively that not only limestone dust, but brick dust, sandstone dust, or any clean stone dust is preferable to ordinary sand. Mr. Alfred Noble and Mr. E. S. Wheeler also found that limestone screenings improved concrete. Experiments made by Mr. Elliot C. Clarke show that the presence of a small amount of clay in concrete is no detriment to its strength, even with clay, as much as 10% of the aggregates and cement combined, and Mr. Ransome cites Niagara gravel, which contains a marked quantity of clay, as making excellent concrete. J. W. Woermann found that impure limestone screenings containing clay, gave greater tensile strength than pure screenings.

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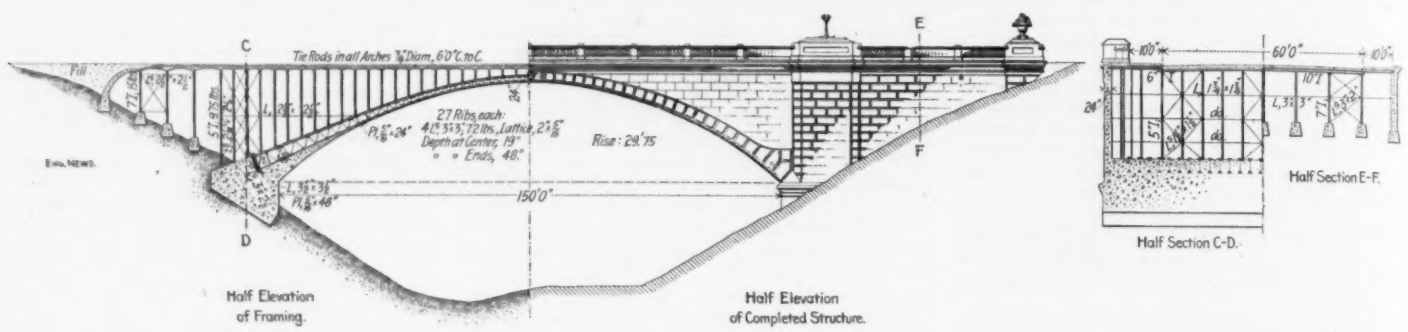

FIG. 6.—PROPOSED CONCRETE AND STEEL ARCH BRIDGE FOR ST. PIERRE HOLLOW, SCHENLEY PARK, PITTSBURG, PA.
Keepers & Thacher, Paterson, N. J., Engineers.

been selected from Engineering News, "Engineering Record," "Municipal Engineering," "Journal of the Western Society of Engineers," and "Trans. Am. Soc. C. E.," to which the writer desires to give due credit. Quotation marks have not been made as a rule, for in most cases the words of the author have been changed, and in all cases when his meaning could be expressed in fewer words, the idea being to present in a clear, brief, condensed form, properly classified for convenient reference, the governing facts relating to concrete construction and the experiments and opinions of many prominent engineers, experts and authorities, who have given the subject years of study and practical application, and when the opinions of engineers of equal eminence do not coincide, the reader must draw his own conclusions.

Portland Cement.—R. L. Humphrey, Inspector of Cements, Department of Public Works, Philadelphia, as a result of over 9,000 tests, from 38 brands of American, Belgian, Danish, English and German cements, shows the superiority of American cements.

Maj. W. L. Marshall, Corps of Engineers, U. S. A., says, if cements do not lose strength under long-time tests, then those cements that give the greatest strength in the shortest time, at least cost, with sand mixtures, are preferred by him, and truthfully adds, that as most work is subjected to its maximum stress within 30 or 60 days, that it matters little after it has failed for lack of strength, that it would have been adamant in strength in one, two or five years.

Sand cement, the invention of F. L. Smidth, of Copenhagen, is made by grinding Portland cement and sand together exceedingly fine, 95% passing through 180-mesh sieve, and is used in the same way as neat cement. It has been used extensively abroad, and to some extent in this country with satisfactory results. It is claimed that sand cement, composed of 1 part cement and 1 part sand, when mixed with sand for mortar and concrete, is superior to neat cement, that it has greater tensile and compressive strength, greater density and coherence, and is more easily worked with a trowel.

Fineness of grinding is very important. Experiments made by C. J. Wheeler, Chemist, gave the following result: (1) Briquettes made from screenings of cement that would not pass 200 sieve, and left in water 40 days, showed no signs of setting. (2) Briquettes made from cement containing 25% of residue on 200 sieve, gave after 7 days 666 lbs. neat, and 213 lbs. for 1 and 3 mortar. (3) Briquettes from fine cement that would all pass 200 sieve, gave after 7 days, 423 lbs. neat, and 366 lbs. for 1 and 3 mortar. The above tests show that the coarser particles are inert, and that neat cement tests have little value. Experiments made by David B. Butler, M. Inst. C. E., lead him to consider that the coarser particles are not inert, but have a certain value, approximately in inverse ratio to their diameter; also that extreme fine grinding decreases its cohesive power, but greatly increases its adhesive power, and value as cement, quickens its setting properties, and largely corrects any tendency to unsoundness. Fine grinding appears to be less important in natural than in Portland cement. Mr. Alfred Noble found that for Louisville cement fineness should depend on the amount of sand used. If 1 to 1, the presence of 20% of coarse particles, that will not pass 80 sieve, is not injurious; if 1 to 2, finely-ground cement is slightly better. This may or may not be true of other natural cements.

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Tests.—Cecil B. Smith, Asst. Prof. C. E., McGill College, considers that neat tests of cement have little value, and that sand tests only are desirable. The Association of German Portland Cement Manufacturers recognize no neat tests for tension or compression, but specify 1 and 3 sand tests. Prof. J. M. Porter, Lafayette College, sent nine samples of cement precisely alike, to nine different expert cement testers, with a request that a 7-day tensile test of 1 and 3 mortar be made according to their understanding of the method proposed by the Committee Am. Soc. C. E. Reports received give average results as follows, each set of five or more tests running quite uniformly:

1.	R. W. Hildreth & Co., New York	75
2.	Prof. Johnson, Washington University, St. Louis	102
3.	H. R. Fehr, City Engineer, Easton, Pa.	114
4.	Prof. W. H. Burr, Columbia College, New York.	136
5.	Chas. F. McKenna, New York, N. Y.	153
6.	Prof. J. B. Spalding, Cornell University	163
7.	Prof. J. M. Porter, Lafayette College	176
8.	Clifford Richardson, Washington, D. C.	225
9.	Booth, Garrett & Blair, Philadelphia, Pa.	247
	Average	153

It is evident from the above that tensile tests can have but little value, unless some more uniform method of mixing and molding is adopted. Mr. Alfred Noble says that it is possible to buy Portland cement of such uniform excellence that little risk is taken in using it without a test. Probably the most extensive and valuable comparative tensile and transverse tests of cement mortars yet recorded were made by Herman E. Abbott and Edwin J. Morrison, Graduates of Thayer School of Civil Engineering. Tests were made on neat cement, and on 1 to 1 and 1 to 2 mortars, the briquettes and prisms being made from the same batch; 700 transverse and 455 tensile tests were made and the average value of "C," which is the

ratio of the actual to the calculated strength from the formula,

$$\frac{W\,l}{4} = \frac{f\,b\,d^2}{6},$$

was found to be about 1.9. The prisms were mostly 1 in. square and 4 ins. span. Transverse tests gave more uniform results than tensile tests, and require no expensive apparatus for making them, and it is a question whether they should not be given preference in specifications.

Consistency of Concrete.—Mr. Ransome states that water enough should be used to render the mass stiff, sticky, tenacious and viscous, and that the theory that only sufficient water should be added slightly to moisten the mass, and hardly enough to render it cohesive in its uncompacted state, is erroneous. He also says that flat tampers should not be used for massive work except in the first and last layers of a day's work; but that thin or edge tampers should be used, and wherever practicable, rolling is preferable to tamping.

A. S. Cooper, U. S. Asst. Engineer, states that cement mortar, with considerable water, has the greatest strength after a long time. Henry Van Arsdale, Racine Construction & Pipe Co., says that 1 and 2 mortar with 40% water gives the best results. Major Marshall believes that an excess of water is injurious, as much in concretes as in mortar, and that where a strong dense concrete is desired, the best results can be had and are had, by using aggregates varying in size; mixing by machinery with water sufficient to give a stiff coherent mass when rammed—all that it will take and allow ramming—the mixing to be made with an intermittent mixer in batches of 1 cu. yd. or more, mixed for as long a time as practicable before incipient set, or without pulverization of stones at angles, and that the ramming into the molds shall be carefully done by corrugated or tooth-faced rammers. Compacting by ramming will give the best possible results, when there shows moisture on the surface, but no slopping or quaking; the extreme proper limit of water supply is indicated by apparent moisture, or incipient quaking. In using broken stone only with all dust and small particles removed, dry mixtures cannot be compacted by ramming unless there is a large excess of mortar over voids, on account of the tendency to wedging or arching of the stones. In such cases, instead of a large excess of mortar, the mortar should be so watered that it will flow into the voids under pressure. A better result will be obtained by mixing the concrete wet, and simply treading it into place, than by mixing dry and failing to compact by ramming. With improper aggregates, poor supervision, and careless construction better results can be had by poor work with wet mixtures, and that a little too wet is better than a little too dry under such conditions.

Mr. Alfred Noble states that for best effect layers of concrete must be from 6 ins. to 10 ins. thick before ramming; that in wet mixtures the sand is more perfectly coated with cement paste; that prolonged ramming on the surface of a dry concrete has little effect in compacting the mortar at the bottom, resulting in alternate dense and porous material; that most English engineers favor wet mixtures that require little ramming; that he believes that a more homogeneous, a denser and stronger material will be obtained if the concrete is made so wet that the mass will quake after ramming. Mr. Noble made upwards of 5,000 tests for the purpose of comparing the strength of mortars of different degrees of plasticity, with the following results:

	Ratios (1 : 1)							
	Portland mortar.				Natural mortars			
Consistency.	30 days.	3 Mos.	6 Mos.	1 y'r.	30 days.	3 Mos.	6 Mos.	1 y'r.
Dry mortar.....	100	100	100	100	100	100	100	100
Moderately stiff ..	97	94	97	97	78	89	95	90
Thin or grout ...	90	92	91	95	63	77	86	82

Geo. W. Rafter (See Trans. Am. Soc. C. E., April, 1899), made tests on 544 blocks of concrete one foot cube, using Genesee, Wayland, Glens Falls, Iron Clad, Empire, and other Portland cement mortars, mixed with broken stone. The mortars were composed of 1 part cement, and 1, 2, 3, 4 and 5 parts of sand, and the volume of mortar used in the cubes was 33% to 40% of the volume of stone. The blocks were crushed on the large testing machine at Watertown Arsenal. The leading idea of the tests was to determine the strength of concretes fabricated with either dry mortars, plastic mortars, and mortars with an excess of water, and the results, using 33% mortar, are as follows, age of specimens not stated:

		Mortar—				
		1 : 1.	1 : 2.	1 : 3.	1 : 4.	1 : 5.
Genesee	Dry..... lbs.	4,130	2,852	3,065	2,059	1,664
	Plastic, "	3,505	.....	2,616	2,036	1,801
	Excess. "	3,622	2,524	2,255	2,416	.....
Wayland ...	Dry..... "	4,267	2,888	2,056	1,810	1,537
	Plastic, "	4,072	2,777	2,207	1,600	1,586
	Excess. "	3,764	2,847	1,723	1,767	1,441
Iron Clad ..	Dry..... "	.....	2,777	1,501	1,412	.....
	Plastic, "	.....	2,552	1,750	1,434	.....
	Excess. "	.....	2,436	1,718	1,594	.....
Empire	Dry..... "	2,659	3,265	1,992	1,666	.....
	Plastic, "	2,593	2,529	2,014	1,523	.....
	Excess. "	2,279	2,890	1,889	1,488	.....

Mr. Charles Hermany, Chief Engineer and Superintendent, Louisville Water Co., who has had much experience in concrete work, and is a close observer, favors a dry mixture. He believes that concrete should never be permitted to give up moisture, but always to absorb it until it shall have become perfectly indurated; he, however, uses a wet mixture for hydraulic work.

Mixing.—Major Marshall says it is possible to increase the strength of concrete 200% over usual practice by prolonged mixing, or materially to reduce the quantity of cement used for the same strength; that the amount of water to use depends on the special conditions of the case, and for hydraulic work recommends wet mixtures. The great strength of the concretes used in the Munderkingen bridge is supposed to be due to the thorough mixing it received. The mixer used was an iron cylinder revolving on a horizontal axis, and containing forty steel balls, weighing altogether 660 lbs. The materials were mixed two minutes dry, and three minutes wet. The 1, 2, 5 and 5 concrete used for the arch gave an average strength of 2,970 lbs. in seven days, and 3,730 lbs. in 28 days. The same kind of mixer was used by Keepers & Thacher in building the Melan bridges at Topeka, Kansas, and Paterson, N. J., but a richer concrete, 1, 2 and 4, was used.

Retempering.—L. H. Goddard and P. P. Evans, Graduates Ohio State University, made a large number of tests to determine the effect of retempering cement mortars. Mortars of 1 to 3 Portland, and 1 to 1 natural, were retempered and mixed repeatedly for eight hours, then made into briquettes which were broken in 7, 28, 56 and 84 days. In all cases a loss of strength was shown from retempering, more in natural than in Portland. Thomas J. Johnson has made similar tests, and thinks it highly probable that no serious injury follows a judicious retempering, but that the process can result in essential destruction of the mortar.

Delay in Placing.—Mr. Ransome says he has experimented with several brands of Portland cement, and found that they were invariably improved in tensile strength by a delay of from one to four hours between mixing and placing.

Connections.—In connecting concrete that has already set with new concrete, Mr. Ransome recommends a wash consisting of a mixture of equal parts of Portland cement and air-slaked lime mixed with water to the consistency of thick cream. Keepers & Thacher specify a mortar of equal parts of Portland cement and sand. The use of lime in place of sand may be an improvement, but the writer knows of no tests in this direction.

Facing.—Major Marshall says he has found it necessary that the facing of works subject to wear shall be of such consistency that no flowing of the mortar shall take place in ramming. If the facing mortar is wet, the writer has noticed that the face is filled with small pits or blow-holes which greatly deface the work. Keepers & Thacher specify that facing mortar shall be composed of 1 part Portland cement, and 2½ parts of sand. This is mixed to the consistency of molders' sand, and rammed or pounded solidly in place. If mixed by hand, the cement and sand is first mixed dry, and cast through a screen, then wetted and turned, and screened again; this latter screening has been found necessary to prevent balling up. If mixed by a continuous mixer, screening will also generally be found necessary; but when mixed by a machine, such as was used at Topeka and Paterson, no screening is necessary, and no trace of pure cement nodules could be discovered in the product. A mixture of 1 part cement and 2.5 parts of sand is preferred for face work, as it makes a dense and practically impervious face, the greatest density lying between 1 to 1 and 1 to 2.5. A poorer mortar than 1 to 2.5 would lack in density, and a richer mortar shows spider web hair-cracks, which look badly, particularly after a rain.

Plastering.—Major Marshall states that the adhesion between natural and Portland cement concretes is not much in excess of one-third the strength of the weaker concrete. He allows no plastering on his work as a rule, but allows a wash of one or more coats of pure cement to fill up pores, and make a more water-tight structure. Thomas J. Johnson states that he has seen Portland cement plastering on natural cement concrete adhere to such a degree that when broken the line of fracture would be through the natural cement concrete. He mentions a dam in the Sanitary District of Chicago, where natural cement concrete was successfully covered with Portland cement plaster, but experiments on briquettes, half-Portland and half-natural cement mortar, were not encouraging for successfully bonding the two mortars when the surfaces of contact are quite smooth.

Freezing.—Percy L. Barker and Henry Allen Symonds, Graduates of Thayer School of Engineering, Dartmouth College, drew the following conclusions, after making 7,150 tests to determine the effect of freezing on Portland and natural cement mortars. (1) Portland cement mortars suffer no surface disintegration by freezing, but the strength is generally injured, and sometimes as much as 40%. (2) Rosendale cement mortar disintegrates on surface, but the interior is not injured. (3) Salt used in the mixing water, one part salt to about 15 parts water, assists Rosendale mortars to resist disintegration, but injures their strength. (4) Salt used as above in Portland cement mortar, decreases loss of strength, the loss not being over 7%. (5) A mixture of Portland and natural cements—Improved Union—gave best results, showing no surface disintegration, nor loss of strength. (6) Rosendale mortar is completely destroyed by immersion in water, which becomes frozen around it.

Tests made by E. H. Connor, at Cairo, show that Portland cement mortar is improved by the addition of salt to the water, 2% of salt adding 6% to the strength, and 12% of salt adding 25% to the strength, the mortar being 1 and 2. He found that Louisville cement mortar loses strength by the addition of salt above 2%. Experiments made by the Austrian Society of Engineers and Architects, showed that lime mortar is unsuitable for freezing weather. Portland cement mortars gave good results, when the water contained 7% of salt. The use of warm water was not found beneficial. Experiments made at Manchester, England, show that frost has a deleterious effect on Portland cement mortar. It suffers most if frozen immediately or soon after mixing. It will improve with time, but probably never regains its original strength.

Experiments made by A. G. Fogg, of Roslindale, Mass., on cement mortar exposed to alternate freezing and thawing lead him to the following conclusions: (1) That it is not safe to allow a slow-setting Portland cement mortar to freeze in less than four days after placing, but that a quick-setting mortar may freeze in 12 hours without injury, if kept frozen until set. (2) If salt is added to the water, the effects of freezing are lessened. (3) That Portland cement mortar is injured more by alternate freezing and thawing, than when it remains frozen until set. (4) That Portland cement mortar will disintegrate when exposed to water and ice, if frozen before it has set hard. (5) That it is not safe to allow Rosendale mortar to freeze in water in less than two months.

Heated Ingredients.—William W. Maclay, M. Am. Soc. C. E., made a series of experiments upon the effects of heating the ingredients of cement mortar, and using the hot mortar at freezing temperatures. Two sets of briquettes were made of 1 and 2 mortar; one at 40° F. and the other at 100° F. They were treated exactly alike, and broken at the same time. The 100° mixture

showed a strength of only 30% of the 40° mixture, and on briquettes of neat cement, the loss of strength was still greater.

Fire.—The following test on a Roebling concrete arch, 4 ft. span, 3 ins. thick, leaded with 150 lbs. per sq. ft., was made Oct. 31st, 1896. After subjecting to a heat of 2,000° F. to 2,300° F. for five hours, water was turned on the hot concrete, and immediately afterwards the arch was loaded with 600 lbs. per sq. ft., without injury. The concrete was composed of 1 cement, 2 sand, and 5 cinders. A similar test was made Sept. 3, with the same result. A test made by the Expanded Metal Co. with the plant of the British Fire Prevention Co., near Regent Park, London, Feb. 14th, 1899, was very satisfactory. A 10-ft. square section of expanded metal flooring—expanded metal imbedded in 3 ins. of concrete, was heated for 15 mins. to a temperature not exceeding 600° F., followed by a fierce fire lasting 1 hr., and gradually increasing to 2,000° F., followed by a sudden application of a stream of water for 3 mins. The central floor beam was deflected, and some plastering fell when water was applied, but the metal lathing was not broken through, and the imbedded metal in the floor proper was not laid bare anywhere. Experiments by T. T. Johnson on concrete mortar briquettes heated in a furnace, showed, however, that they were much weakened by the heat. There is no question that concrete, and concrete-steel construction is fireproof to a greater degree than any other building material known.

Effect of Sea Water.—The report of the Committee of German Portland Cement Manufacturers on the action of sea water on cement, states that sea water weakens Portland cement, also that all samples to which slaked lime had been added were strongly attacked. Tests made by Herr Sympher, Inspector of the Baltic Ship Canal, show that sea water weakens mixtures of Portland cement and sand; also cement, sand and slaked lime; Roman cement, trass, and puzzuelona cements, all showed decidedly lower tests in salt water than in fresh. Hydraulic lime mortar, 1 to 1, showed especially bad results, the test pieces being in part destroyed at one and two years. Mr. Wm. Michaelis, cement expert of Berlin, states that a completely impervious mortar is necessary to prevent washing out, and that one part of cement to two or 2½ parts sand was the highest compatible with complete impermeability; to this the requisite quantity of gravel or ballast should be added. Chemically, cements rich in silica, and as poor as possible in alumina and ferric oxide should be used, and that no hydraulic cements stand better in sea water than those which consist almost entirely of silica and lime.

The following are the specifications of Keepers & Thacher, relating to concrete steel bridges:

Specifications for Concrete Steel Bridge.

Plans.—The work shall be constructed complete in accordance with the general plans, sections and diagrams herewith submitted, and these specifications. The specifications and drawings are intended to describe and provide for the complete work. They are intended to be co-operative, and what is called for by either is as binding as if called for by both. The work herein described is to be completed in every detail, notwithstanding that every item necessarily involved is not particularly mentioned. The contract price shall be based upon these specifications and drawings, which are hereby signed and made a part of the contract.

Conditions of Calculation.—

Modulus of elasticity of concrete	1,400,000 lbs.
Modulus of elasticity of steel	28,000,000 "
Maximum stress per square inch on steel	10,000 "
Maximum compression per sq. in. on concrete	500 "
Maximum shear " " "	100 "
Maximum tension " " "	50 "

The above are to be exclusive of temperature stresses. The steel ribs under a stress not exceeding their elastic limit must be capable of taking the entire bending moment of the arch, without aid from the concrete, and have a flange area of not less than 1-150 part of the section of concrete at crown.

Discrepancies.—In the event of any discrepancies between the drawings and the figures written on them, the figures are to be taken as correct, and in case of any discrepancy between the drawings and the specifications, the specifications are to be adhered to.

Foundations.—All foundations shall be shown on plans, and conform to the dimensions marked thereon. Foundations on rock shall be prepared by removing all sand, mud, or other soft material, and by excavating the bed rock in such manner as may be described or shown on drawings. Foundations on hardpan, gravel, gravel and clay, cemented sand, or other material intended to carry the load without piles, shall be excavated to the depths shown on plans.

Foundations on piles when not otherwise described, shall be enclosed in a permanent coffer dam or crib, and be excavated to the depths shown on plans, and the piles shall be driven after the excavations are made. The spaces between the piles shall be filled with concrete, and in case it is found necessary to lay the concrete under water proper appliances must be used to insure its being deposited with as little injury as possible. The piles shall be oak, yellow pine, or other wood that will stand the blow of the hammer, straight, sound, and cut from live timber, trimmed close, cut off square at the butt, and have all bark taken off. The piles shall not be less than 12 ins. nor more than 16 ins. in diameter at the large end, nor less than 10 ins. in diameter at the small end for piles having a length of 30 ft. and under. For greater lengths the diameter of small end may be reduced 1 in. for each 10 ft. of addtional length down to a minimum of 7 ins. The piles shall not be loaded with a weight greater than given by the following formula: $L = 2\,w\,h \div (s + 1)$, in which L = safe load in pounds; w = weight of hammer in pounds, h = fall of hammer in feet, s = last penetration in inches. The number and arrangement of the piles for each foundation shall be shown on plans, and they shall be sawed off at the elevation shown.

Cement.—The cement shall be a true Portland cement, made by calcining a proper mixture of calcarious and clayey earths; and if required, the contractor shall furnish a certified statement of the chemical composition of the cement, and the raw materials from which it is manufactured. The fineness of the cement shall be such that at least 99% will pass through a sieve of 50 meshes per lin. in., at least 90% will pass through a sieve of 100 meshes per lin. in., and at least 70% will pass through a sieve of 200 meshes per lin. in.

Samples for testing may be taken from each and every barrel delivered unless otherwise specified. Tensile tests will be made on specimens prepared and maintained until tested at a temperature of not less than 60° F. Each specimen will have an area of 1 sq. in. at the breaking section, and after being allowed to harden in moist air for 24 hrs. will be immersed and maintained under water until tested. The sand used in preparing the test specimens shall be clean, sharp, crushed quartz, retained on a sieve of 30 meshes per lin. in., and passing through a sieve of 20 meshes per sq. in. No more than 23 to 27% of water shall be used in preparing the test specimens of neat cement, and in the case of test specimens of 1 cement and 3 sand, no more than 11 or 12% of water by weight shall be used.

Specimens prepared from neat cement shall after seven days develop a tensile strength of not less than 450 lbs. per sq. in. Specimens prepared from a mixture of 1 part cement and three parts sand, parts by weight, shall after seven days develop a tensile strength of not less than 160 lbs. per sq. in., and not less than 220 lbs. per sq. in. after 28 days. Specimens prepared from a mixture of 1 part cement and 3 parts sand, parts by weight, and immersed after 24 hours in water maintained at 176° F., shall not swell nor crack, and shall, after seven days, develop a tensile strength of not less than 160 lbs. per sq. in. Cement mixed neat with about 27% of water to form a stiff paste, shall after 30 mins. be appreciably indented by the end of a wire 1-12-in. in diameter loaded to weigh ¼-lb. Cement made into thin cakes on glass plates, shall not crack, scale nor warp under the following treatment: Three pats will be made and allowed to harden in moist air at from 60° to 70° F.; one of these will be subjected to water vapor at 176° F. for three hours, after which it shall be immersed in hot water for 48 hours, another shall be placed in water at from 60° to 70° F., and the third shall be left in moist air. All cement shall be kept housed and dry until wanted in the work.

Portland Cement Concrete.—The concrete shall be composed of clean hard broken stone, or gravel, with irregular surface; clean, sharp sand, and cement, mixed in the proportions hereafter specified. Whenever the amount of work to be done is sufficient to justify it, approved mixing machines shall be used. The ingredients shall be placed in the machine in a dry state, and in the volumes specified, and be thoroughly mixed, after which clean water shall be added and the mixing continued until the wet mixture is thorough and the mass uniform. No more water shall be used than the concrete will bear without quaking in ramming. The mixing must be done as rapidly as possible and the batch deposited in the work without delay.

If the mixing is done by hand, the cement and sand shall first be thoroughly mixed dry in the proportions specified. The stone previously drenched with water shall then be deposited on this mixture. Clean water shall be added and the mass be thoroughly mixed and turned over until each stone is covered with mortar, and the batch shall be deposited without delay, and be thoroughly rammed until all voids are filled. The grades of concrete to be used are as follows: For the arches between skewbacks—1 part Portland cement, 2 parts sand, and 4 parts broken stone, or gravel, that will pass through a 1½-in. ring; for the foundations, abutments, piers and spandrels—1 part Portland cement, 4 parts sand, and 8 parts broken stone, or gravel, that will pass through a 2-in. ring.

Concrete Facing.—If concrete facing is used, it shall be composed of 1 part Portland cement, and 2½ parts sand, and shall have a thickness of at least 1 in. on all arch soffits, arch faces, abutments, piers, spandrels or other exposed surfaces. There must be no definite plane or surface of demarkation between the facing and the concrete backing. The facing and backing must be deposited in the same layer, and be well rammed in place at the same time. If the arch faces, quoins or other exposed surfaces are marked to represent masonry, such division marks shall be made by triangular strips 2 ins. wide and 1 in. deep fastened to the casing in perfectly straight and parallel lines, and all projecting corners will be beveled to correspond.

Plastering.—No plastering will be allowed on the exposed faces of the work, but the inside faces of the spandrel walls covered by the fill may be plastered with mortar having the same composition as specified for facing.

Stone Facing.—If stone facing is used, the ring stones, cornices and faces of spandrels, piers and abutments shall be of an approved quality of stone. The stone must be of a compact texture, free from loose seams, flaws, discolorations, or imperfections of any kind, and of such a character as will stand the action of the weather. The spandrel walls will be backed with concrete, or rubble masonry, to the thickness required. The stone facing shall in all cases be securely bonded or clamped to the backing. All stone shall be rock faced with the exception of cornices and string courses, which shall be sawed or bush-hammered. The ring stones shall be dressed to true radial lines, and laid in Portland cement mortar, with ¼-in. joints. All other stones shall be dressed to true beds and vertical joints. No joint shall exceed ½-in. in thickness, and shall be laid to break joints at least 9 ins., with the course below. All joints shall be cleaned, wet and neatly pointed. The faces of the walls shall be laid in true lines, and to the dimensions given on plans, and the corners shall have a chisel draft 1-in. wide carried up to the springing lines of the arch, or string course. All cornices, moldings, capitals, keystones, brackets, etc., shall be built into the work in the proper positions and shall be of the forms and dimensions shown on plans.

Brick Facing with Concrete Trimmings.—The arch rings, cornices, string courses and quoins, shall be concrete faced as described above, the arch rings and quoins being marked and beveled to represent masonry. The piers, abutments and spandrels shall be faced with vitrified brick as shown on plans. The brick facing shall be plain below the springing lines of the arches, and rock faced above these lines. All rock faced brick shall be chipped by hand from true pitch lines. All brick facing shall be bonded as shown on plans, at least one-fifth of the face of the wall being headers. The brick must be of the best quality of hard-burned paving brick, and must stand all tests as to durability and fitness required by the engineer in charge. The bricks must be regular in shape and practically uniform in size and color. They shall be free from lime and other impurities; shall be free from checks or fire cracks, and as nearly uniform in every respect as possible; shall be burned so as to secure the maximum hardness; so annealed as to reach the ultimate degree of toughness; and be thoroughly vitrified so as to make a homoegeneous mass. The backing shall be carried up simultaneously with the face work, and be thoroughly bonded with it.

Artificial Stone.—All keystones, brackets, consoles, dentils, pedestals, hand-railing posts, and panels, and other ornamental work when used, also curbs and gutters, shall be of the designs shown on plans, and be molded in suitable molds. The mortar for at least 1-in. thick shall consist of 1 part Portland cement and 2½ parts sand, and when the size of the molding will admit, the interior may be composed of concrete of the same composition as specified for the arches. When pedestals, posts or panels carry lamp-posts a 4-in. wrought-iron pipe shall be built into the concrete from top to bottom, and at bottom shall be connected with a 3-in. pipe extending under the sidewalk, and connected with gas pipe or electric wire conduit. The pipes shall have no sharp bends, all changes in direction being made by gentle curves.

Sprinkling.—During warm and dry weather, all newly built concrete shall be well sprinkled with water for several days, or until it is well set.

Mixtures.—The volumes of cement, sand, and broken stone in all mixtures of mortar or concrete used in the work, shall be measured loose.

Connections.—In connecting concrete already set with new concrete the surface shall be cleaned and roughened, and mopped with a mortar composed of 1 part Portland cement and 1 part sand, to cement the parts together.

Arches.—The concrete for the arches shall be started, simultaneously from both ends of the arch, and be built in longitudinal sections wide enough to inclose at least two steel ribs, and of sufficient width to constitute a day's work. The concrete shall be deposited in layers, each layer being well rammed in place before the previously deposited layer has had time to set partially. The work shall proceed continuously day and night, if necessary, to complete each longitudinal section. These sections while being built shall be held in place by substantial timber forms, normal to the centering and parallel to each other, and these forms shall be removed when the section has set sufficiently to admit of it. The sections shall be connected as specified above, and also by steel clamps or rib connections built into the concrete.

Drainage.—Provision for drainage shall be made at each pier as follows: A wrought-iron pipe of sufficient diameter shall be built into the concrete, extending from the center of each space over pier to the soffit of the arch near springing line, and project 1 in. below the soffit. The surface of concrete over piers shall be so formed that any water that may seep through fill above will be drained to the pipes. The line of drainage wil be covered with a layer of broken stones, and the top of pipes will be provided with screens to prevent clogging.

Steel Ribs.—Steel ribs shall be imbedded in the concrete of the arch. They shall be spaced at equal distances apart, and be of the number shown on plans. Each rib shall consist of two flat bars of the sizes marked on plans. The bars shall be in lengths of about 30 ft., thoroughly spliced together, and extending into the abutments as shown. Through the center of each bar shall be driven a line of rivets spaced 8 ins. c. to c., with heads projecting about ⅜-in. from each face of bar, except through splice plates, where ordinary heads will be used. The bars shall be in pairs with their centers placed 2 ins. within the inner and outer lines of the arch respectively as shown. All steel must be free from paint and oil, and all scale and rust must be removed before imbedding in the concrete.

The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material and turned or planed parallel. The area of cross-section shall not be less than ½-sq. in. The elongation shall be measured after breaking on an original length of 8 ins. Each melt shall be tested for tension and bending. Test pieces from finished material prepared as above described shall have an ultimate strength of from 60,000 to 68,000 lbs. per sq. in.; an elastic limit of not less than one-half of the ultimate, shall elongate not less than 20% in 8 ins., and show a reduction of area at point of fracture of not less than 40%. It must bend cold 180° around a curve whose diameter is equal to the thickness of piece tested without crack or flaw on convex side of bend. In tension tests the fracture must be entirely silky.

Rivet Steel.—Test pieces from finished material prepared as above described shall have an ultimate strength of from 54,000 to 62,000 lbs. per sq. in., an elastic limit of not less than one-half of the ultimate strength, shall elongate not less than 20% in 8 ins., and show a reduction at point of fracture of not less than 50%. It must bend cold 180° and close down on itself without fracture on convex side of bend. In tension tests the fracture must be entirely silky.

Inspection.—The contractor shall furnish a testing machine of the proper capacity and shall prepare and test without charge such specimens of steel as may be required to prove that it comes up to the requirements mentioned above.

Workmanship.—The rivet holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven. When members are connected by bolts, the holes must be reamed parallel and the bolts turned to a driving fit. Rivets must completely fill the holes, have full heads concentric with the rivets, and be machine driven when practicable.

Centering.—The contractor shall build an unyielding falsework or centering. The lagging shall be dressed to a uniform size so that when laid it shall present a smooth surface, and this surface shall conform to the lines shown on the drawings. The center shall not be struck until at least 28 days after the completion of the arch. Great care shall be used in lowering the centers so as not to throw undue strains upon the arches. The tendency of the centers to rise at the crown as they are loaded at the haunches must be provided for in the design, or if not, the centers must be temporarily loaded at the crown, and the load be so regulated as to prevent distortion of the arch as the work progresses.

Casing.—When concrete facing is used, all piers, abutments, and spandrel walls shall be built in timber forms. These forms shall be substantial and unyielding, of the proper dimensions for the work intended, and all parts in contact with exposed faces of concrete shall be finished to a perfectly smooth surface, by plastering or other means, as that no mark or imprfection shall be left on the work.

Waterproofing.—After the completion of the arches and spandrels, and before any fill is put in, the top surface of arches, piers, and abutments, and the lower 6 ins. of the inner surface of the spandrel walls shall be covered with a suitable waterproof material, so as to exclude water effectually.

Fill.—The space between spandrel walls shall be filled with sand, earth, cinders, or other suitable material, and be thoroughly compacted by ramming, steam road roller, saturating with water or other effective means, and be finished to the proper grade to receive the curbing and pavements.

Granitoid Sidewalks.—The spaces over which the sidewalks are to be laid shall first be covered with 6 ins. of cinders well compacted. On this shall be laid 4 ins. of concrete, consisting of 1 part Portland cement, 3 parts sand, and 6 parts broken stone or gravel—small size—well rammed. The flag divisions shall then be marked off to the desired size. On the surface of the concrete shall then be laid a wearing surface 1 in. thick, composed of 2 parts Portland cement and 3 parts broken granite or other acceptable stone, in size from ⅝-in. downward. It shall be well rammed and troweled to a perfectly even surface and rolled with a toothed roller. This wearing surface must be spread on the concrete while the latter is still soft and adhesive, and neat connections must be made with cornices and curbs.

Roadway Pavement.—The pavement shall be of the kind shown on plans or mentioned in proposal, and shall be built according to the specifications adopted in the locality where used, unless otherwise mentioned.

Retaining Stone.—There shall be set at each end of roadway pavement a line of stones of approved quality 4 ins. in thickness and 18 ins. deep, with top surface conforming to contour of pavement.

Balustrades and Hand-Railings.—The balustrades shall be of the material, and of the form and dimensions shown on plans, and shall be brought to true alinement and be firmly fastened to the outside of each sidewalk in the position shown. If an iron hand-railing is used, it shall receive two coats of approved paint after erection.

Erection.—The contractor shall employ suitable labor for every kind of work, and all stone work shall be laid by competent masons. The contractor will furnish all staging, piling, cribbing, centering, casing and material of every description required in the erection of the work; also all plant, including dredges, engines, pumps, derricks, barges, mixing machines, pile drivers, conveyors, or other appliances necessary for carrying on all parts of the work. The contractor shall assume all risks for loss or damage incurred by ice, floods, fire, or other causes during the construction of the work, and shall sufficiently watch and light the work at night during construction.

Cleaning Up.—Upon completion of work, and before final acceptance thereof, the contractor shall remove all temporary work from the river and all rubbish from the streets.

Maintaining Public Travel.—If public travel is to be maintained during the construction of the new bridge, by the removal of old bridge, construction of temporary bridge or otherwise, special mention of the same shall be made.

Removal of Old Bridge.—If the site of the proposed structure is occupied by an old bridge, the same shall be removed by the contractor. The iron work shall be piled on the bank, and the timber and stone shall become the property of the contractor.

Work Embraced by Contract.—The work embraced by contract will be for the structure complete from out to out of abutments or retaining walls, as per plans and specifications, and will embrace fill, pavement, sidewalks and balustrades complete for this length, unless otherwise mentioned.

Approaches.—The approaches will commence where the work above mentioned ends, and if all or any part of them is included in contract the same shall be specially mentioned.

Changes.—The committee in charge shall have power to direct changes which they may consider necessary or advisable in any part of the work, and such changes shall not in any way violate the contract, but the value of such changes shall be added to or deducted from the contract price, and any dispute as to their value shall be settled by arbitration in the usual way.

Inspection.—All material furnished by the contractor shall be subject to the inspection and approval of the committee in charge.

Lamp Posts, Trolley Poles and Name Plates.—If used these shall be shown on plans, or be specially mentioned.

Interpretation of Plans and Specifications.—The decision of the committee in charge or their engineer shall control as to the interpretations of drawings and specifications during the execution of the work thereunder, but this shall not deprive the contractor of his rights to redress after the completion of the work, for any improper orders or decisions.

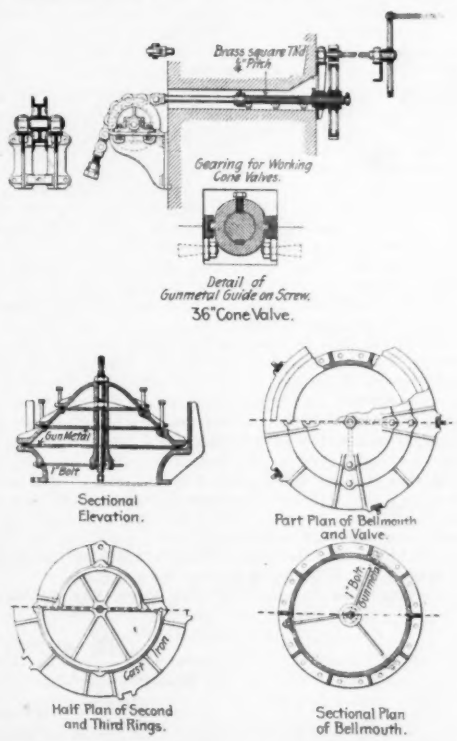
Estimates.—Approximate estimates of work done and material delivered, shall be made on or about the last day of every month, and a valuation of the same in proportion to contract prices for the completed work will be made by the committee in charge or their engineer, which sum shall be paid to the contractor in cash, on or before the 10th day of the following month, less a deduction of 10% upon said valuation, which shall be retained until the final completion of the work.

Final Payment.—Upon the final completion of the work, the contractor shall be promptly paid any balance of the contract price which shall then remain due and unpaid.

CONE RESERVOIR OUTLET VALVES, PLYMOUTH, ENGLAND.

The bell-mouthed ends of the outlet pipes of the new Burrator reservoir at Plymouth, England, are provided with cone valves, seating in the bell-mouth. The valves are intended for emergency use, to shut off the water in case the ordinary valves in the chambers just below the dam need to be repaired. Their simplicity of construction and operations make a valve chamber and tower on the inner side of the dam unnecessary. Cone valves have been used for this purpose before,* but the valves at the Burrator reservoir are especially designed to facilitate handling under heavy water pressure. The exact pressure is not stated, but the dam is a masonry structure, 77 ft. high. There are three outlet pipes, 36, 30 and 25 ins. in diameter, respectively. Only the 36-in. valve is described, the smaller ones differing only in having fewer lifts. A description of these valves was presented to the recent meeting of the Institution of Mechanical Engineers, by Mr. Edw. Sandeman, M. Inst. M. E., Borough Water Engineer of Plymouth. The facts already presented have been taken from the paper, as well as the accompanying illustration. Further details can be given best by quoting from the paper, as follows:

The largest of the valves, which have been called cone valves from their conical shape, is designed to act upon the open end of a 36-in. pipe, which has a bell-mouth measuring 48 ins. across. It is divided into three circular segments faced with gun-metal. A 3-in. gun-metal spindle



Details of Cone Reservoir Outlet Valve, Plymouth, England.

Edw. Sandeman, M. Inst. M. E., Borough Water Engineer.

runs vertically through the center of the valve, which is lifted and lowered together with the separate parts of the valve by gearing placed in a chamber at the top of the dam. Gun-metal rods (and chains passing over pulleys where there is a change of direction) connect the spindle to the gearing.

In opening, the upper circular section, which is the smallest, is first raised by the spindle to a height of 4 ins., when it engages the heads of four bolts connecting it to the second section of the valve, and as it continues to rise, this second part also is lifted, rising to a height of 6 ins. above the third. By similar means the third section is raised from its seating to a height of 12 ins., so that the valve being fully open leaves three circular spaces through which water can enter the bell-mouth outlet-pipe. All lateral motion of the different parts of the valve is prevented by guides and stays. The total area of the spaces is nearly three times that of the sectional area of the pipe, with the object of considerably reducing the velocity of the water passing through. The action of the four valves at work has been very satisfactory. In the future design of similar valves an air-pipe rising above water-level from the top of each valve might be provided, and for this purpose the vertical spindle might be made hollow.

The reservoir has a capacity of 780,000,000 U. S. gallons. Besides the masonry dam mentioned, there is an earth embankment. The water drawn from the reservoir is measured by a Venturi meter, on the 25-in. supply main, the throat of the tube being diminished in size to 11 3-16 ins.

*See Eng. News, Dec. 15 and 22, 1892, article on new reservoir at Butte, Mont.

MODERN DEVELOPMENTS IN TRACK AND TRACK WORK.*

By E. E. Russell Tratman.‡

Two years ago I had the pleasure of addressing this Association at Old Point Comfort, on the subject of the duties and responsibilities of the roadmaster, and the important relation which his work bears to the operation and finances of the railway. On accepting the invitation to address you again I concluded to present some remarks upon certain features of modern developments in track and track work, feeling sure that this subject would be of interest. I shall confine my remarks mainly to improvements and changes which depart somewhat from general practice.

To begin at the foundation, which is an important feature of every construction, I would call your attention to a bold, and at first rather startling, idea for dispensing with ballast, and using instead a permanent concrete foundation. This subject was recently discussed in Engineering News,† and aroused considerable interest. To show the important advantages of securing a permanent bed for the track, which will not require continual attention and repair, it may be explained that about one-sixth of the total cost of operating our railways is expended on the mere care and maintenance of the track, exclusive of bridges, culverts, fences, etc. In the year ending with June, 1898, the railways expended $81,360,000 (or nearly 10% of the total operating expenses) in repairs of roadway, exclusive of $10,662,000 for rail renewals and $24,770,000 for tie renewals.

The system of track construction with cross-ties in a bed of ballast is so well established and so universally adopted, that it seems almost sacrilege to criticise it or to suggest its abolition, but while it is economical in first cost, it is so expensive in maintenance, that in these days of low interest charges and small profits, railways may well consider whether it might not be economy to introduce a different and more permanent system.

In the early days of railways, and again within recent years, continuous longitudinal bearings have been tried as a substitute for the intermittent bearings of cross-ties. The results, however, have not in general been satisfactory, although the advantages of this system in regard to maintenance have led to its extensive adoption for bridges and tunnels in other countries. The great difficulty has been in keeping the track in proper line and surface, and it has even been suggested that for tracks carrying very heavy traffic, the rails should be laid on longitudinals supported on cross-ties. This would be a development of the old style of street railway track construction.

Nearly all proposed plans for improved track, however, retain the bed of loose ballast, and it is very generally assumed that ballast is an absolute necessity. Suppose we break away from this idea, and consider the possibility of introducing a permanent foundation to which the rails may be directly secured. Two methods have been described (Engineering News, Jan. 5, 1899), and while there are plenty of points for criticism in both these designs, it is more important to consider whether they represent, in principle, some good features to be introduced in future track construction. As to the cost, the real question is whether the railway can by adopting such a system save enough in annual operating expenses to pay the interest on the cost of making the change, with a small profit besides.

From future possibilities let us return to matters of present practice. Everybody knows the defects of ordinary sand and gravel ballast in making a dusty roadbed, much to the discomfort of passengers, especially in summer, when the heat makes it desirable to have the windows open. To check the nuisance from dust, several railways are now sprinkling the ballast with oil, and this treatment is meeting with much success. This practice originated with Mr. J. H. Nichol, Assistant Engineer of the West Jersey & Seashore Ry., in 1897, and it has since been followed on the Pennsylvania R. R., Boston & Maine R. R., Long Island R. R., Chicago, Burlington & Quincy R. R., and others. It not only provides for the comfort of passengers, but also reduces the chances of hot boxes, checks the growth of weeds, and reduces the heaving action of frost.

The oil used is a residuum of crude petroleum, having a high fire test, low gravity and only a faint smell. The first application requires about 2,000 gallons per mile, and about 500 to 600 gallons per mile per year will suffice to keep the ballast dustless, after tie renewals, etc. The sprinkling train is run at a speed of about 3½ to 4 miles per hour. In front is a flat car, fitted with a 2-in. pipe across between the rails, and a 2-in. swinging pipe on each side, all these pipes having slots in the under side. The supply is brought from a tank car to these pipes by a 4-in. main. The regulating valves and the swinging pipes are all controlled from levers or handles on the flat car. With the pipes swung out, a width of 15 to 20

*Abstract of an address delivered before the Roadmasters' Association of America, at the annual meeting at Detroit, Mich., Sept. 13.
‡Associate Editor of Engineering News.
†Engineering News, Jan. 5 and March 23, 1899.

ft. of roadbed may be sprinkled. The rails are protected by shields.

Our next step is from ballast to ties, and one of the most notable improvements of recent years is the more general attention given to the advantages of subjecting wooden ties to chemical treatment to increase their life. By efficient treatment, timbers which are of a very inferior quality when green, may be made at least equal to good white oak in durability and will cost about the same as, or even less than, the untreated white oak. This means not only a direct saving in money, but also a reduction in track work and expenses, and an improved condition of track. The reason for the latter is that the longer you can keep your track in condition without disturbing it for tie renewals, the better it will be. The two preservatives most extensively used are creosote (or dead oil of coal tar) and chloride of zinc. The latter is more generally used in this country on account of the high cost of creosote. The Chicago Tie Preserving Co. has recently completed a portable plant, which can be sent to any part of the country to undertake contracts, being set up on temporary side tracks close to the source of supply of ties (Eng. News, Aug. 17, 1899).

The chemical treatment, however, will not, as a rule, prevent the rails from cutting into the ties, and so metal tie-plates are used on both green and treated ties. Several millions of these plates are now in service, and their wide introduction has led to the use of special tools for embedding them in the tie, and for setting them in proper position relative to the rail.

The use of steel ties continues to extend in Europe and other countries, but is making little (if any) progress in this country. Steel ties have been tried more extensively by the New York Central R. R. than by any other road, but the results have not been entirly satisfactory. This road has, at Garrison's, N. Y., about 1,576 ft. of track laid with 721 of Hartford's ties. These have proved durable, having been in use ten years, but to keep them in surface requires nearly twice as much work as for wooden ties. They are also said to be hard to line, while the ballast shakes away from them and they give a rattling sound from the stone ballast and the bolts. Near 110th St., New York city, this road has about 3,375 ft. of track laid with 1,350 steel ties of a modified form, known as "ox-bow" ties, from their shape, the depressed center part being covered with ballast. These are being replaced with oak ties. They were less satisfactory than the others.

We now come to the subject of rails, and reference may be made to the Manning unsymmetrical rail, about 1,500 tons of which have been ordered for experimental purposes. It is claimed that its life will be nearly twice that of an ordinary rail before being taken out of main track, but it is doubtful whether any such result will be obtained. The increased life is to be attained simply by the addition of a thickness of $^3/_{64}$-in. on top of the head, and about $^1/_4$-in. of metal on the gage side of the rail head, so that one-half of the head is wider than the other. The idea is that the rails will give their full life before being turned, the inventor claiming that turned rails do not give a good bearing for the wheels (Eng. News, Feb. 9, 1899).

As to improved fastenings of rails to the ties, I am sorry that there is nothing to say. A few small experiments have been made with screw spikes, but apart from that we still nail our rails to the ties with more or less inefficient spikes, which require constant attention. This is a discouraging condition for a structure which costs millions of dollars yearly for maintenance. There is little prospect of any better device being introduced, but bolts, wedges or clamps must be used with steel rails on a concrete substructure.

Coming to the question of joints, however, it seems to me that one of the most important steps which has been taken, is that of providing some form of base support for the ends of the rails, this base being supported either by the ties or by some part of the joint device. Of equal importance are the efforts to improve the quality of the metal in the splice bars and to improve the fit between the bars and the rail. As a general thing they should be of harder steel, and more carefully fitted to give a full even bearing.

In regard to switches, the only great novelty is the Duggan switch, having rails moving vertically instead of horizontally. It seems, however, that it has not come up to the expectations, the greatest difficulty being that the diversity of distance back to back of wheels leads to derailment. The switch is therefore not found advisable for use where trains run at high speed. All the ordinary and slip switches of the Boston Terminal are of 100-lb. rails and are fitted with an anti-creeping device invented by Mr. E. H. Bryant, Roadmaster of the N. Y., N. H. & H. R. R.

The switches on the sharp curves of the Chicago elevated loop have an interesting arrangement for the support of the switch rail. A guard rail is placed close to the stock rail on the side of the curve, and is extended back of the switch rail, so that when the switch is set for the curve the switch rail is firmly supported to resist the blows from the wheel flanges in taking the curve.

The standard switches of the Netherlands State Railways have pivot joints, instead of bolted splice bar joints, at the heels of the switch rails (Eng. News, Sept. 7, 1899). Cast-steel frogs are standard on those lines. Attention may also be called to the use of angle iron for frog guard rails. The Duluth & Iron Range R. R. uses angle irons 6 × 6 ins. for frogs made of 100-lb. rails.

Frog substitutes, which give an unbroken rail for the main track or the siding, according to the position of the switch, date back 40 years or more, but have not met with much favor. In most of these cases the principle is the same. The turnout lead rail is elevated sufficiently to bring the wheels up so that their flanges will clear the top of the main rail. This main rail is continuous, and in the gap by which it passes through the turnout lead is a pivoted rail of special shape, operated in connection with the switch. This rests upon the main rail when the switch is set for the siding. An automatic connection is provided, so that a main line train trailing through a frog set for the siding, will throw the frog open and so set the switch before the train reaches it. A careless man might simetimes throw the switch before a train taking the siding had cleared the frog, and would thus open the frog and cause a derailment. To prevent this, a detector is sometimes applied, as in interlocking work, to prevent the switch from being thrown until every wheel has cleared the fouling point.

It has been objected that the connections between the switch and frog are liable to derangement by creeping or expanding track, and are also liable to injury if a car comes off the siding when the switch is set for the main line. These particular objections, however, do not seem to have much force when we consider the great extent and successful operation of interlocking apparatus and connections. Only a few weeks ago, I traveled several hundred miles over a road which has practically all of its main sidings or passing places fitted with derails connecting up to the switch. This, of course, requires a longer connection than from a switch to a frog. Of course the frog substitute or "frogless frog" has its limitations, the same as the spring rail frog. It is not desirable for general use in yards, where quick switch throwing is necessary. For sidings in limited use, where the heavy wear of frogs (even spring rail frogs) is out of all proportion to the actual duty performed in carrying wheels in and out of sidings, it would seem very desirable to have an unbroken main rail, and this appears to open a field for the frog substitute.

One of the first of these devices to be put into actual service is that patented in 1884 by Mr. Charles B. Price, now General Superintendent of the Allegheny Valley R. R. Several are now in use on that road. Up to March, 1899, about 150 of the MacPherson frog substitutes had been put in service on the Canadian Pacific Ry., and during four years' service they have shown but little wear, while the cost of maintenance has been very small, according to the testimony of officers of the road. When set for the siding it has been trailed through by a main line train, and has been run through as a misplaced facing switch by an express train, without damaging the frog or causing a derailment, in spite of the elevation.

The Coughlin swing-rail frog (Eng. News, Nov.18, 1897) is on the same principle, but the load wing rail does not move. The frog rail is the only moving part, and is made of a piece of track rail, instead of being a heavy casting, as in the Price frog. This device is being tried by several railways. It is a pity that some practical arrangement of this sort cannot be devised for giving an unbroken rail at crossing frogs, at reasonable expense. The Fontaine crossing did effect this, but was expensive and in other ways unsatisfactory, and never came into more than experimental use.

At the present time there is an extensive introduction of metal as a substitute for wood for signs and fencing. Sheet-iron signs or posts of angle iron or tubes can often be made economically from scrap material, or they can be purchased ready made.

In methods of handling and distributing material for raising and ballasting track, widening banks, and filling trestles, great advances have been made, largely in the rapid handling of great quantities of material, thus greatly reducing the cost of the work. A steam shovel is far more effectual and economical than the biggest and quickest gang of shovelers in loading gravel on dump cars.

To spread and level the ballast, "spreader" cars fitted with hinged wings or gates are sometimes used. In ballasting with the Rodger car the ballast is deposited in a ridge between the rails by hopper bottom cars, and at the rear of the train is a flat car fitted with a scraper or plow. This throws a portion of the ballast out over each rail and levels it down, while flangers clear the rail and form a flangeway. The ties can then be jacked up and have the ballast shoveled and tamped under them.

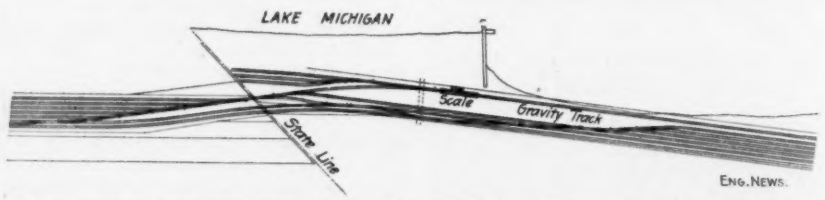
One other class of work to which I will refer is that of filling trestles by the hydraulic method. Ordinarily, the work is done by shoveling or dumping material from work trains. Both the Canadian Pacific Ry. and the Northern Pacific Ry., however, have made use of the hydraulic system, which is cheap and causes no obstruction to the track, though it is a somewhat slow process. The water is brought by pipes from an elevation, and is thrown in powerful jets against the hillside. The stream of water and gravel, or earth, is carried by a flume to the site of the bank, the end of the flume being shifted as desired. The water runs away, leaving the solid material behind, which forms a very close and compact bank.

In the construction and repair of trestles, docks, etc., and in the construction of temporary structures at washouts, a track pile-driver is a most useful machine. The horizontal bed is carried by a turntable, so that it can be swung round to drive piles on either side of the track. The bed can also be run forward so that piles can be driven 16 ft. ahead of the car. The leaders can also be inclined sideways, to drive brace or batter piles. An ordinary drop hammer is generally used, but this is sometimes replaced by a steam pile-hammer. The engine can be used for hoisting and handling piles, and can be connected by gearing to the rear truck so as to propel the machine at about 5 miles an hour.

WEIGHING CARS ON A GRAVITY TRACK; CHICAGO, LAKE SHORE & EASTERN RY.

The weighing of cars in railway freight yards is usually the cause of more or less delay in and interference with the general work of the yard, as each car has to be run on the scale, stopped, and then coupled up and hauled off. In the yard of the Chicago, Lake Shore & Eastern Ry., at the Illinois and Indiana state line, the cars are weighed as they pass over a scale placed on a gravity track. The accompanying cut shows the plan of the yard and the position of the scale. The distinctive features of the operation of the yard are: (1) the facility of operation; and (2) the method of handling the cars in being switched from the train to the scale and to the yard tracks beyond. At this yard is received all material coming from the south and east, and destined for the South Works and the Joliet Works of the Illinois Steel Co.

All cars entering or leaving the yard are weighed on a Fairbanks' track scale 100 ft. long. The scale beam rider is provided with type-metal members, which, by the act of weighing, stamp the car weight on a card inserted in a slot in the rider.



PLAN OF STATE-LINE FREIGHT YARD, SHOWING CAR WEIGHING SCALES ON GRAVITY TRACK; CHICAGO, LAKE SHORE & EASTERN RY.

The card has had the car initial and number written on it before the car has passed entirely onto the scale platform. The gross and tare weights can be stamped in position, so that it is not necessary to rewrite them in order to get the net weight. This reduces the chance of error, and makes the record of weights unquestionable.

The track leading to the scale has a capacity of 35 cars, and is on an ascending grade to a point about 100 ft. from the scale. From this summit the track has a down grade of 0.5% to and over the scale, and beyond it to the storage yard. In weighing cars, they are pushed up the approach track by a locomotive, and the speed is so slow that as each car is sent over the summit the train comes to a stop without taking up the slack of the draft rigging, the couplers just touching. The train moves forward a car length at a time, and the jerking and pulling which ordinarily accompany the weighing of cars is entirely absent. This, of course, does away with a considerable amount of racking wear and tear on the draft rigging.

As the first car of the train reaches the summit, the car (being uncoupled) runs by gravity down

grade to the scale. The cars are so timed in passing over the summit, as to give a space of about 100 ft. between the car on the scale and the one approaching. The time available for weighing averages from 10 to 15 seconds per car. The car does not stop, but continued to move on over the scales and down the track to the storage yard. When it has nearly reached the entrance to the yard, it is mounted by a brakeman, who checks its speed so that it comes to a standstill on reaching the car ahead without shock. There are five brakemen employed in this service in weighing a full-length train. They have so accustomed themselves to regulate the speed of the cars, that they can catch two or three cars at a time and conduct them on to the storage siding as skilfully as though they were handling one.

The time of weighing depends on the speed of the car in going down the grade by gravity, which is largely governed by the weight of the car, the nature of the wind, and the initial speed of the car on cutting loose from the train. In the ordinary service of the yard, a 40-car train of coke has been weighed and put away on the siding in 17 minutes. The capacity of the scales is so great that night weighing has been abolished, thereby saving the expense of a night crew and locomotive. It should also be noted than when the cars are weighed they at once pass into the yard without any expense for rehandling or switching till the engine comes to take them away to the point of delivery of their contents, and when the last car has been weighed the engine is free to do other work at once.

The system was designed by Mr. M. M. Richey, General Superintendent of the Chicago, Lake Shore & Eastern Ry., and was installed under his direction. The scale has now been in satisfactory operation for two months. For particulars of this interesting feature in yard work we are indebted to Mr. Victor Windett, M. West. Soc. C. E., of Chicago, who is civil engineer of the South Works of the Illinois Steel Co.

SUBWAY TRANSFORMERS.

There is a growing tendency in cities to remove all electrical conductors from poles and place them underground in conduits. In the case of alternating circuits a place must also be found for the step-down transformer, which, when the lines were carried on poles, was generally hung on a cross-arm. As it is inadvisable to bring high tension circuits into buildings, the transformers cannot be located there. In Europe the matter is arranged by building a small house or kiosk espe-

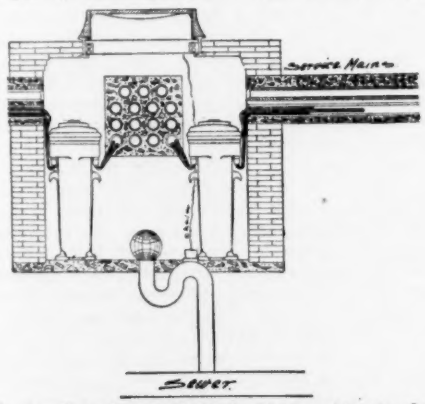


Fig. 1.—Transformer Manhole, Designed by the General Electric Co., Schenectady, N. Y.

cially for the transformer and its accompanying switches and fuses. In this country, however, it is more customary to place the transformer in an underground chamber or manhole, such as is shown in Fig. 1.

Special precautions must be taken to prevent the access of water to the windings in designing the transformer case for use under such conditions. In Fig. 2 is shown the case for a 10-K-W. oil-insulated transformer designed for subway service. The lead-covered cables are brought in through the metal bushings projecting downwards under the rim. The cable covers are soldered by a plumber's wiped joint to these bushings, after which the latter are drawn up against a faced seat by bolts inside the case, thus making the connection perfectly water-tight. A sufficient number of bolts are provided to securely hold the cover to the rim of the box, both of which have machined surfaces. An elastic packing or gasket is used to insure tightness. Projecting from the cover will be seen a short nipple for the attachment

FIG. 2.—SUBWAY TRANSFORMER, MANUFACTURED BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

of a pipe reaching above the highest possible water level in the manhole. The object of this is to allow for the free expansion of the oil and the escape of gases which may be formed within the case. Lifting lugs are provided, placed on the smaller diameter of the cross-section, where they will not take up valuable room.

For the information here given, and for the cuts used, we are indebted to the General Electric Co., of Schenectady, N. Y.

RAINFALL IN NICARAGUA.*

By A. P. Davis, Hydrographer, United States Geological Survey.

The Nicaragua Canal Commission made certain investigations of the climatology of Nicaragua in 1898. The form of rain gage used at most of the stations was a metal funnel, which caught the rain and discharged it into a bottle, from which it was measured in a graduated glass bearing a known relation to the diameter of the funnel. The gage was always placed in a position as exposed as possible; but nearly always this was a small clearing in the forest, which was still well sheltered from the wind.

One of the most remarkable characteristics of Nicaragua is its rainfall and the radical and striking differences in amount and distribution of precipitation on the east and west coasts. From the rainfall tables it will be seen that at Greytown, on the Rio Deseado, and other points near the Atlantic, there is no definite dry season, but that rain may be expected any day in the year, and the expectation will seldom be disappointed. On the Pacific coast, on the contrary, there is no rain from the beginning of the record in January until the middle of May, when the rainy season begins, after which it is subject to violent downpours throughout the rainy season, the precipitation for a single day observed at Brito, on the 23d day of May, being 5.06 ins.

No less remarkable is the excessive aggregate of rainfall in a limited district of which the nucleus seems to be in the vicinity of Greytown. The annual rainfall at this point, as deduced from the mean of four years' observation, is about 250 ins., while that at Bluefields is only about 90 ins., at Port Limon somewhat less, and at San Jose de Costa Rica about 68.

While there is a slight increase of rainfall with altitude at the headwaters of the Deseado and San Francisco, yet, in general, it may be said that the rainfall decreases as we pass up the San Juan River. No definite limit can be assigned, with present information, to this district of excessive rainfall, nor is it known in what ratio precipitation decreases to the northward and southward.

The dividing line between the characteristic climates of the east and west is not definite, but may be said, in general, to approximately coincide with the range of mountains known in canal literature as "the Eastern Divide." The portion west of this divide partakes of the characteristics of the Pacific slope, having a comparatively moderate precipitation and a definite division of rainy and dry seasons, while the territory east of this divide has no well-defined dry season and has much heavier rainfall than the west side. The exception to this rule is the valley of the San Juan. As we proceed up this river the rainfall decreases rapidly and almost uniformly, but the dry season is by no means well defined and rain may be expected in any month.

Thus, so far as quantity and distribution of rainfall alone is concerned, the conditions are rather unfavorable to the requirements of the canal. The heaviest engineering constructions are to be on the east side, where the rain is excessive and persistent, thus interfering with construction and with the permanence of the works. On the other hand, the entire basin of Lake Nicaragua, upon which the canal must depend for its water supply, is affected by a long dry season, in which evaporation from the lake is greatly in excess of the inflow, and storage must be provided to overcome this drain.

On the west side, including the basin of Lake Nicaragua, the dry season begins in December and ends in May—being ordinarily from one to two months shorter than the rainy season. During the latter part of the dry season the inflow to the lake becomes very slight, many of the tributaries, though wide and deep, are filled with stagnant water, upon which grows enormous masses of floating vegetation, which discolors the water, renders it foul, and obstructs navigation. When the rains begin in May or June these streams are swollen to almost torrential proportions and flow with strong currents far out into the lake, carrying great masses of vegetation or floating islands, sometimes acres in extent, and become a source of serious annoyance to the steamers plying on the lake. These floating islands are eventually broken up by the winds and waves of the lake, and such parts as are not discharged through the San Juan River, decay in the lake.

*From the "Monthly Weather Review."

Monthly Rainfall in Nicaragua During 1898.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Brito	0.25	....	0.08	0.08	11.30	14.86	11.42	6.18	16.82	25.70	6.01	2.41	95.11
Las Lajas	.25	0.05	1.34	.28	10.60	13.50	10.64	8.44	6.79	16.19	4.41	2.26	74.75
Rio Viejo	.04	.01	.66	.00	13.78	13.45	4.01	11.66	7.28	8.99	0.61	0.17	60.66
Tipitapa	.26	.00	.26	.00	8.56	16.88	6.24	7.82	11.25	7.12	0.93	0.17	59.49
Morrito	...	...	...	.07	8.92	14.05	13.84	10.20	....	....	....	....	.....
Fort San Carlos	...	...	1.21	3.00	8.22	15.56	13.35	8.00	10.56	8.93	9.86	5.62	84.31
Sabalos	...	...	2.10	6.00	11.69	17.13	20.69	11.33	11.42	11.81	12.17	10.20	104.54
Castillo	...	...	...	...	.....	.....	18.92	11.46	16.22	2.99	14.04	11.64	.....
Machuca	...	...	...	...	.....	.....	.....	6.52	12.86	9.83	15.65	.....	.....
Rio San Carlos	...	...	7.52	11.67	20.13	20.73	18.26	11.68	.....	....	.....	.....	.....
Ochoa	13.07	14.07	8.04	12.22	15.24	21.44	21.58	12.06	15.12	8.02	21.50	8.38	170.74
San Francisco*	15.33	18.43	8.72	11.25	13.87	18.87	19.22	13.45	10.95	9.09	22.38	10.61	172.17
Sarapiqui	...	...	...	...	.....	.....	.....	.....	11.19	11.35	18.63	7.12	.....
Deseado†	21.92	26.98	11.76	8.83	14.84	18.96	26.86	13.31	5.23	11.92	29.25	21.07	210.63
Greytown	19.44	25.17	10.16	7.82	9.37	19.52	24.63	16.38	7.24	12.50	32.35	17.06	201.64

*Record incomplete from Jan. 1 to 5, inclusive, and from Dec. 29 to 31, inclusive, so the rainfall at Ochoa for those days is added.

†Rainfall not observed from Dec. 25 to 31, inclusive, so the record was completed by including the corresponding days for 1897.

ALUMINUM PLATES AS A SUBSTITUTE FOR LITHOGRAPHIC STONE is one of the innovations now in successful use, says "The Mineral Industry." Experiments in this line have been going on for some years; but Josef Scholz, of Mainz, is now using 5-lb. sheets of aluminum as a substitute for the usual Solenhofen limestone slabs weighing 50 to 100 lbs. The aluminum sheets are polished with ground pumice; dried and washed with a patent acid solution, and when again dried are ready for the imprint. The advantages are many. The aluminum sheets cost one-third that of the stone; errors are easily corrected by washing out the ink with acid; no liability to fracture under heavy pressure; space saved in storage and labor in handling. The quality of work done on the metal plates is said to be excellent, and lighter or rotary presses can be used with them. Several establishments in the United States now use the aluminum plates and rotary presses. The owners of the two processes—the Mullaly and Stoecker-Scholz—have now consolidated.

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ADVERTISING RATES: 20 cents a line. Want notices, special rates, see page XXII. Changes in standing advertisements must be received by Monday morning: new advertisements, Tuesday morning; transient advertisements by Wednesday morning.

We are sure that our readers will appreciate the value of the extended review, which we this week present, of the subject of combined concrete and steel bridge construction. There is not much doubt that the present greatly increased disposition among engineers to use concrete masonry, both in monolithic form and with an imbedded metal skeleton, for bridges, is one of the most noticeable developments of recent years in bridge engineering, and the author of the article which we publish, Mr. Edwin Thacher, M. Am. Soc. C. E., is an engineer especially well qualified by training and experience in all classes of bridge work to speak with authority on this new departure. In the construction of combined concrete and steel bridges, Mr. Thacher's experience has probably exceeded that of any other American engineer. We shall not attempt to review the article at all fully here. Much that it contains has, as some of our readers will doubtless observe, already appeared in our columns during the past few years, but we may, we think, reasonably plead in extenuation of its partial repetition now that the collection of the various scattered facts and opinions in one place will attract attention to them which would be denied by many persons if they had to search a score or more of the bulky volumes of this journal. In some respects the most particularly useful portion of the article to our mind is the specification for concrete steel bridges with which it closes. This specification not only embodies the writer's conclusions regarding many of the disputed questions which he brings up in the body of his article, and which he has there left open, but it is the most complete specification for this class of structures, if not the only one of any pretension, which has been printed anywhere. Another point which the article brings up, and which it seems to us is worth the most careful study, is the extension of the combined concrete and steel system of arch construction to long spans of from 200 ft. to 500 ft. In beauty of form and material nothing excels the masonry arch for a bridge in the majority of locations, and the concrete-steel arch, while differing widely from solid masonry in certain particulars, is susceptible to the same æsthetic treatment. Beyond a certain length of span, however, the all-metal structure is unrivaled by the masonry arch because of the excessive cost and practically prohibitive difficulty of constructing the latter with such great spans. These objections, Mr. Thacher claims, do not extend to the combined concrete and steel construction to nearly so great an extent; one particular case of a 300-ft. span of concrete and steel construction being mentioned, where the prices actually bid for its construction were but a trifle greater than for the steel arch which was afterwards built on the same site. The longest span concrete bridge so far built in America is 125 ft., but European engineers have gone considerably beyond this limit. For these long spans European engineers have, however, adopted the solid concrete arch with hinges instead of the combined concrete and steel system of construction. Mr. Thacher's remarks upon this hinged construction will, we believe, prove interesting reading, even if his views are not coincided in by all. In conclusion, we believe that a little warning will not be out of place in regard to engineers basing their opinion as to the merits of combined concrete and steel for bridge construction too much upon the behavior of some of these bridges which have been built in the past. As in every other new method of construction knowledge here has had to be gained by experience, and it is reasonable to anticipate that some of these earlier concrete structures erected by engineers of varying experience, and not always, it is fair to presume, with the best material and workmanship and with possibly serious errors in design, are going to show the ultimate endurance and durability which will be obtained with the more carefully designed structures which are now being built. It is quite remarkable, however, when we come to look for failures of this sort in concrete arch construction, how few serious ones we find. In some respects this is the most convincing proof which we have of the fact that engineers in adopting this concrete and steel construction have not been basing their practice upon unsafe premises.

The overcrowding of westward bound transatlantic steamers with steerage passengers is a matter frequently complained of in the newspapers, but we have yet to learn that any attempt has been made by the United States government to remedy the evil. A recent instance of overcrowding was brought to the attention of a member of the staff of this journal, who crossed on the steamer "Werkendam," of the Holland-American line, leaving Amsterdam Aug. 17, and Boulogne-sur-mer on Aug. 18. According to the U. S. Certificate of Inspection, posted in a prominent place on the vessel, she carried eight boats, four of them life boats, and three life rafts, carrying capacity of boats and rafts not stated, and 318 cork life preservers, and the vessel was allowed to carry 112 cabin and 128 steerage passengers, a total of 240. The vessel actually carried, however, on this trip, 86 cabin and about 550 steerage passengers, a total of more than two-and-a-half times the number allowed by the U. S. Inspectors, or twice as many passengers as there were life belts. If the vessel had collided with an iceberg, a derelict or another vessel, and the crew and passengers been forced to take to the boats, the horror of the situation may be imagined. Allowing that 112 life belts were in the rooms of the cabin passengers, and, therefore, inaccessible to the steerage, and that some of the remaining belts were appropriated by the crew, there would be 206 life belts to be divided among 550 steerage passengers; and it is not possible that the life boats and rafts were anywhere near sufficient to accommodate both passengers and crew, numbering over 700 in all.

The facts above stated were communicated by letter to Mr. J. A. Dumont, Supervising Inspector General of the U. S. Steamboat Inspection Service, and he replies as follows:

Sir: Referring to your letter of 8th inst., in relation to excess of passengers on the steamship "Werkendam" over that allowed by her U. S. certificate of inspection, on her voyage from Amsterdam, arriving at New York, Aug. 29th ult., you are informed that the U. S. certificate only covers the voyage from the United States to a foreign port; the United States inspection laws having no force on steamers bringing passengers to the United States.

Very respectfully, Jas. A. Dumont,
Supervising Inspector General.

It appears, then, that the United States inspection laws offer some assurance to an American citizen, who makes a trip to Europe, that, on the outward voyage, when the vessel takes the southern passage, to avoid the fogs on the banks of Newfoundland and the icebergs, and when there is no fear of the boat being overcrowded with steerage passengers, there will be enough life boats, rafts and life belts for the use of all the passengers and crew, but that on the homeward voyage, when the vessel takes the northern route, passing through the fogs on the banks, and when the steerage is packed with immigrants from Russia and Southern Europe, United States laws offer him no protection whatever.

If United States laws are competent to restrict immigration by means of medical inspection, by the returning at the expense of the steamship companies, those immigrants who are likely to become paupers, by the contract labor law, and by the entire exclusion of the Chinese, it would appear that they should also be competent to restrict it by imposing a heavy fine on vessels which arrive at our ports crowded with passengers far beyond the limit which the law permits on outward voyages. A law imposing such a fine, and a stringent enforcement of it, has a much stronger reason for existence than simply the desire to restrict immigration. It is that is necessary to reduce the dangers to human life of the transatlantic passage.

We give considerable space in this issue to the report of the Walker Commission on the Nicaragua Canal, which was delivered to the President on May 29 last. A brief summary of this report was given out by the State Department, and was printed in our issue of June 8, but the full text of the report has been withheld from the public. "The New York Journal," however, in its issue of Sept. 10, published what it claims to be the full text of this report, and as it bears on its face evidence that it is, at least for the most part, genuine, we have deemed it proper to present the salient parts of this report for the benefit of our readers.

We shall not attempt a critical discussion of this report since it will not form the basis of any action, the whole matter being now in the hands of the new Commission, whose appointment was recorded in our issue of March 23. We do think it well to point out, however, that the present report of the Walker Commission thoroughly substantiates the position which this journal has maintained respecting the Nicaragua enterprise. We have urged in season and out of season, that the United States Government should not enter into partnership with, loan its credit to, or purchase the concession of the old Maritime Canal Co., of Nicaragua, until it had examined through a competent enginering commission the entire enterprise. Both the Ludlow Commission of 1895 and the Walker Commission of 1897 have now reported, and each one discards the main features of the old Maritime Canal Company's scheme, and it is now dead beyond hope of resurrection. Both these reports affirm the feasibility of a Nicaraguan ship canal; and in our opinion the country is likely to get one a good deal sooner than it would have done had the Nicaragua company's boomers in the early 90's been successful in their attempt to secure a government endorsement of the canal company's bonds.

Had the government funds been spent on such works as the Ochoa and La Flor dams, the Divide cut and the San Francisco embankments, it is altogether likely that the outflow from Uncle Sam's pocket would have reached such an amount that public opinion would have compelled the withdrawal of the government's credit, and the consequent financial collapse of the enterprise.

THE CONTRACT FOR THE ENGINES OF THE MUNICIPAL ELECTRIC RAILWAYS OF GLASGOW, SCOTLAND.

An interesting controversy has arisen in Great Britain over the recent action of the Town Council of Glasgow in connection with the bids for four

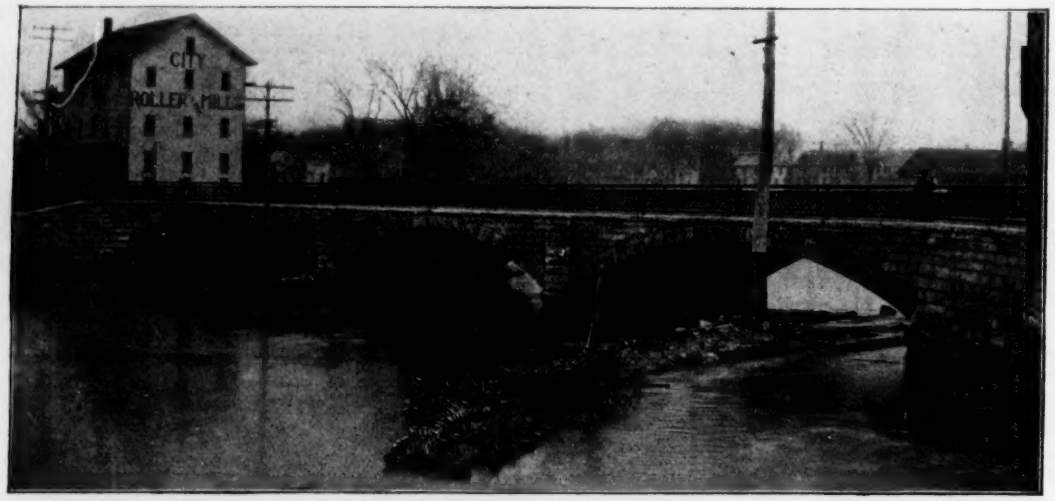


FIG 1.—STONE FACED ARCH BRIDGE AT ALBION, MICH.

FIG. 2.—ALBION, MICH., BRIDGE IN PROCESS OF CONSTRUCTION.

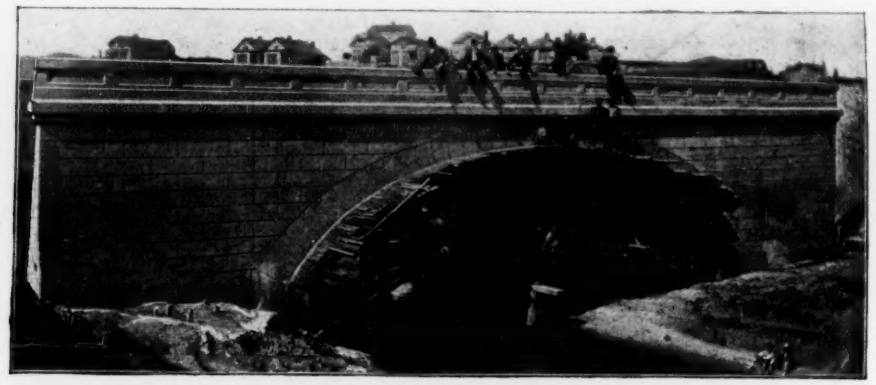


FIG. 5.—HIGHWAY BRIDGE AT KENTUCKY ST., LOUISVILLE, KY.

FIG. 3.—STONE FACED ARCH BRIDGE AT TECUMSEH, MICH.

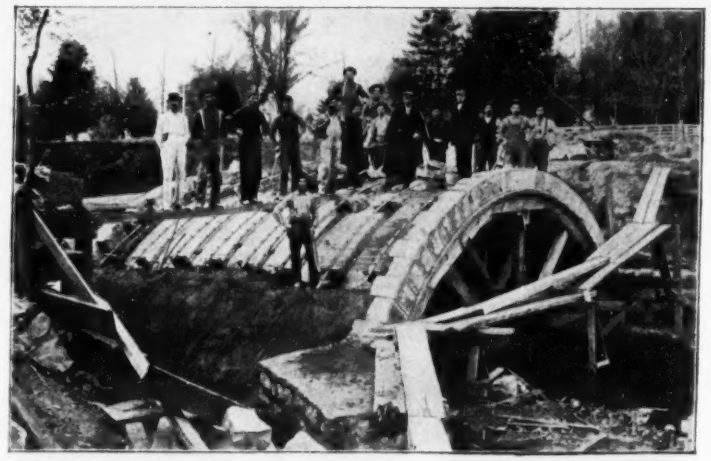


FIG. 4.—BRIDGE AT TECUMSEH, MICH., UNDER CONSTRUCTION.

RECENT EXAMPLES OF CONCRETE AND STEEL ARCH BRIDGES.

Keepers & Thacher, Paterson, N. J., Engineers.

4,000-HP. and two 800-HP. steam engines for the new power station which will supply current for electric street railways of the city. A brief history of the case is as follows: The city which owns and operates the street railway lines within its borders decided to introduce electric traction. It therefore sent Mr. John Young, general manager, and Mr. W. H. Clark, engineer, of its tramways to the United States to obtain information concerning the best system to adopt. Subsequently Mr. H. F. Parshall, M. Am. Inst. Elec. E., a well-known American electrical engineer, who has offices in London, was called in as consulting engineer, and he prepared general specifications, the most important features of which are given in the following extracts:

Proposals are requested for four vertical compound-condensing engines, fitted with valves and gear of the Corliss or other approved type, and having the rotating part of the electric generator mounted on an extension of the main crank shaft, and the stationary part either carried on a separate foundation or an extension of the main engine base-plate.

Each proposal must be accompaniel by the following detail drawings:

Drawing showing construction of piston and rings, connecting-rods, main bearings, fly-wheel, crosshead and slippers, and the following information, viz.:—(1) Diameter of cylinders and stroke of engines; (2) arrangement of valves, valve gear and governor; (3) diameter and length of main bearings; (4) diameter of body of main crank shaft; (5) diameter and length of crosshead pins; (6) diameter and length of crank pins; (7) weight of frame and bed plate; (8) diameter and weight of fly-wheel; (9) weight of the engine complete; (10) method of lubrication; (11) the guaranteed steam consumption per indicated and per brake horse-power per hour, including jackets and re-heating coils, when working at three-quarter load, full load, and an overload of 25% beyond its normal capacity, with the use of steam containing not more than 2½% of moisture, and working condensing with a vacuum equivalent to 25 ins. of mercury; (12) the guaranteed ratio of indicated to brake horse-power; (13) the shortest time required to deliver the first engine, second, third and fourth engines respectively, and erect each complete in perfect running order from the date of closing the contract.

The engines shall be delivered within the time herein mentioned. In case the contractor is unable to meet the requirements of this specification as to the delivery, a statement containing the dates within which he can guarantee delivery shall accompany the tender. Time allowed for delivery—first engine, 11 months; second engine, 13 months; third engine, 14 months; fourth engine, 15 months. Damages for non-fulfilment of contract per day, £25.

The conditions under which each engine will work are as follows: (a) The normal steam pressure delivered at the throttle valve of each engine will be 150 lbs. per sq. in., the steam being superheated. (b) The normal vacuum, as measured at the exhaust pipe of each engine, will be equivalent to a column of mercury 25 ins. in height. (c) The normal speed of each engine will be 75 revolutions per minute.

Each engine must be so designed and constructed as to develop 4,000 I.HP. at its normal load, or when giving an electric output of 2,500 K.-W and capable of developing a maximum continuous power of 5,000 I.HP.

Each engine is to be of the automatic cut-off type, and so designed as to automatically control its speed without further readjustment or changes in the regulating devices when once properly set to meet the service requirements, all of which are based on a wide open throttle and normal steam and vacuum conditions, and shall further be provided with one emergency valve, of approved type, for cutting off the entire supply of steam from the engine, the valve to work both by hand and by a special automatic governor operating the same at 5% increased speed. The engines shall not race under any condition of load, viz., from no load to the maximum load, and the speed shall not vary more than 1½% above and 1½% below the normal speed of 75 revolutions per minute on any variation that may occur from no load to the maximum load, and shall not vary more than 1½% from the normal speed of 75 revolutions per minute when operating without any load, nor during a revolution at constant load shall angular velocity vary more than ⅛%.

Each engine must be so constructed that it can be operated non-condensing in case of emergency without necessitating the stoppage of the engine.

In the preparation of these specifications engines of the following general dimensions have been deemed suitable. In order, however, that contractors have fullest latitude in the use of standard designs, these dimensions do not form a part of the specification.

Three-cylinder vertical, compound, condensing, direct-coupled engine, 75 revolutions, 150-lb. steam pressure, 2,500 K-W. output. The engine to have one high-pressure and two low-pressure cylinders.

High-pressure cylinder	42 ins. × 60 ins.
Low-pressure "	60 " × 60 "
" "	60 " × 60 "
Crosshead pins	12 " × 12 "
High-pressure crank pin	20 " × 12 "
First low-pressure crank pin	16 " × 12 "
Second low-pressure crank pin	12 " × 12 "
First section shaft	22 ins. diamet'r
Second " "	24 " "
Third " "	36 " "
First and second journals	22 ins. × 36 ins.
Third and fourth journals	24 " × 36 "
Fifth and sixth journals*	32 " × 64 "
Outer bearing	30 " × 48 "
Wheel, 26-ft., 10 segments, to weigh about	275,000 lbs.
One high-presure piston-rod	9 ins. diamet'r
Low-pressure piston-rod	10 "
Steel pistons and crossheads	

*Between high-pressure and fly-wheel, and between fly-wheel and generator.

The fly-wheel and generator to be placed either on the high-pressure or low-presure side. The shaft to be bored out one-third (⅓) of its diameter.

Alternate Design.—Two-cylinder cross-compound condensing engines, 75 revolutions, 150 lbs. steam 2,500-K-W.

High-pressure cylinder	44 ins. × 60 ins.
Low-pressure cylinder	88 " × 60 "
Crank pins	12 " × 14 "
Crosshead pins	12¼ " × 14 "
Shaft	34 "
Journals	32 " × 64 "
Wheel, 24-ft., 10 segments, to weigh about	275,000 lbs.
High-pressure piston-rod	9 ins.
Low-pressure piston-rod	10 "
Steel pistons and crossheads	
Hole, 12-in. diameter, through shaft.	

Several bids were received for the engines, among them the following:

Bidder.	Price.	Weight, each large engine, tons.
D. Stewart & Co, Glasgow	£54,880	486
Hick, Hargreaves & Co., Ltd., Bolton.	94,900	600
The E. P. Allis Co., Milwaukee	114,554	700
The E. P. Allis Co. (auxiliary)	8,375	...
Harvey & Williams, U. S. A.	160,000	...

On Aug. 15 the Tramway Committee of the Glasgow Corporation considered the several bids. Mr. Parshall advised the acceptance of the E. P. Allis Co.'s bid, on the ground that their engine was the best for the purpose. This firm, he said, accepted the specification throughout, with the reservation that they might be allowed to construct a heavier machine if, as the work progressed, they found it desirable to do so. A motion to accept the tender of the E. P. Allis Co. was then carried by a vote of 7 to 6 in the Tramways Committee, but this acceptance was subject to confirmation by the Council. The latter body on Aug. 17 rejected all the bids, and by a large majority voted to ask Mr. Parshall to draw a new specification, on which every firm would be able to tender on the same basis.

The action of the Committee and the Council was followed by a lively controversy, both in the daily newspapers and in the engineering journals. "The Engineer" of Aug. 25, says, editorially:

We have before us a minute of the sub-committee on traction, which contains Mr. Parshall's reasons for giving the contract to the American firm. The document is private, and we could not publish it without a breach of good faith. We may say, however, that we cannot accept the explanations given by Mr. Parshall as satisfactory. On the other hand, it must be admitted that English and Scotch firms do not appear to have gone the right way to work to secure the order. The tender of D. Stewart & Co., Limited, is evidently based on some mistake. The engines asked for could not be made for the money. But, on the other hand, if Mr. Parshall had made himself familiar with the prices paid by the Admiralty and our great shipping firms for engines of 5,000 HP., he would have seen that the price asked by the American firm is extremely high. It is no less than £20,000 over that of Hick, Hargreaves & Co., Limited. One other firm appears to have made a mistake of some 200 tons in calculating weights. A more serious ground of complaint is that the British firms tendering all wanted a much longer time for executing the order than did the American firm, who undertook to deliver in 20 months from the date of the order, as compared with from 24 to 30 months asked by the English firms. Mr. Parshall bases most of his arguments in favor of the American tender on the greater weight of the American engines. He holds, obviously, that only the American firm understands what are the difficulties to be overcome and the troubles to be anticipated; and, in fact, maintains generally that English and Scotch firms do not comprehend the nature of the work to be done, and the magnitude of the stresses to be sustained. This is, we think, quite natural on the part of an American engineer; but it is scarcely fair to Englishmen.

Messrs. Hick, Hargreaves & Co. naturally felt aggrieved because they did not secure the contract when their bid was £20,000 less than that of the E. P. Allis Co. In one of their letters to the press they criticise the suggestions of Mr. Parshall in regard to design of the engines, as being "difficult for an engine-builder to take seriously," such as:

1. Piston-rods of the same size for the 88-in. low-pressure cylinder of the two-crank design, and for each of the two 60-in. low-pressure cylinders of the alternative three-crank designs. 2. Crosshead bearings as large or larger than the crankpin. 3. Crankpins very much smaller thn the crankshaft necks. 4. Crankshaft bearings of an extravagant size. 5. An oil pump called for of a "capacity equal" to a two-gallon lubricator.

Messrs. Hick, Hargreaves & Co., further complain of unfair treatment by the Tramways Committee in depriving them of sufficient opportunity to explain reasons for each point in their design, which differed from that suggested by Mr. Parshall.

On the other hand, The E. P. Allis Co. also gave their side of the case to the public, and their letter is an excellent specimen of vigorous English. We quote from it as follows:

There was nothing in the specification at which any one familiar with the demonstrated requirements of large electric plants could cavil. Naturally it did not follow British practice, for the exceedingly simple reason that there is no such application of electric power in the United Kingdom. It was simply a model plant designed in the light of great modern experience, with a view to rendering the best economies to the municipality to which it was offered. The only "anomalies" discovered by our competitors arose out of their ignorance of the conditions that exist, and their inexperience of those methods of construction which have been found the best.

The long and short of it is that instead of meeting the question openly and fairly, our competitors have endeavored to bring such pressure upon the Glasgow Corporation as may induce it to accept an article of their manufacture, even if it be inefficient, unreliable or antiquated.

If that end be attained, we fail to see that any result is gained by the Corporation from a long and careful study of electric traction which has been made by the Tramway Committee and its engineers, involving expensive journeys to visit the representative modern systems of the United States and Europe.

We feel ourselves aggrieved, and, we think, justly.

Our tenders, prices and specifications have been openly discussed and every advantage now given to our competitors. We can see little of that "fairplay," so hypocritically invoked, in a "competition" which is re-opened whenever a home competitor fails to secure the contract, or in re-casting specifications until the favored bidder finds them adapted to his limitations. To invite American houses to offer under such conditions is not only absurd, but radically wrong. If the game is to be played under such rules, it would be vastly fairer to exclude the American manufacturer altogether, and not invite him to expend his time and money needlessly.

It is undoubted that a municipality has every right to decide to support home industry to the exclusion of all outsiders, but it may very properly be questioned whether the proper time to arrive at that conclusion is after outsiders, at the request of the municipality, have placed at its disposal all their data under the mistaken supposition that serious business was offered.

There are more than two sides to this interesting question, and some valuable lessons in regard to the best plan for letting large contracts for machinery, may, we think, be learned from it.

There are the two sides of Messrs. Hick, Hargreaves & Co. and the Edward P. Allis Co., each of whom has an ox which has been gored. The former believe they should have the contract because they think their engine is as good as the Allis Co.'s, and because they were the lower bidder; the Allis Co. thinks it is wronged, for the reasons stated in its letter.

Then there is the side of the Glasgow Corporation, its Tramways Committee and Mr. Parshall. The action of the Corporation is found fault with by both of the engine-building firms, but how could it have done differently without being justly subjected to far more extensive criticism than it has received. Had it given the contract to the Allis Co., without having it clearly shown by the opinion of other engineers besides Mr. Parshall, that the Allis engines were worth £20,000 more than those of Hick, Hargreaves & Co., and without giving the latter firm a full opportunity for presenting their case, it would have experienced a storm of criticism from the Glasgow taxpayers. Had it given the contract to Hick, Hargreaves & Co., it would have been criticised, probably justly, for not availing itself of the greater experience of the American firm in building large engines for electric railway service, and for adopting an antiquated and inefficient engine in its place.

Under all the circumstances, the bids having been received, and the Tramways Committee having voted, by the narrow majority of 7 to 6, to recommend the Allis engines, it seems that the Corporation has acted not only within its moral and legal rights of rejecting any and all bids, which rights it had no doubt reserved in its original call for bids, but that its action was the best possible for the taxpayers' interest, which interest, as trustee of the taxpayers, it is bound to conserve, if it can do so without infringing on the rights of others.

What other action, antecedent to calling for bids, could the Corporation have taken, which would have avoided the likelihood of such a controversy as has taken place? One course is suggested in the letter of the E. P. Allis Co., in these words:

A municipality has every right to support home industry to the exclusion of all outsiders.

But if Glasgow had excluded American bidders from the competition it would not have been to the interest of the taxpayers. It would have prevented the Corporation from availing itself of American experience, and it might also have tended to raise the price of the engines.

Another course is suggested editorially by "Engineering" as follows:

We think the Glasgow Corporation made a mistake in not issuing complete drawings in the first instance. They knew that these engines far exceeded in size anything which had been attempted in this country for a similar purpose, and that the problem was one of considerable difficulty. . . . As a mere matter of economy, it is evidently cheaper to make drawings in this country than

to bring 3,000 tons of machinery over the 4,000 miles intervening between Glasgow and Milwaukee.

We cannot agree with this opinion. In such a new business as the building of 4,000-HP. engines for large electric railways, the experience gained in the last five years has been so great, and the modifications of designs have been so numerous, that it is next to impossible for any consulting engineer, not in the employ of a large engine builder, to become so familiar with the very latest practice of the best shops in the world, as to be able to make complete drawings of an engine which, when finished, will be undoubtedly equal to the best engine ever built. "Engineering" suggests that Mr. Parshall should have made the drawings, saying that he is "an engineer who is minutely acquainted with everything connected with the subject, and who is able to put the British engineers on a parity with those in America."

This is no doubt a greater claim for the all-round ability of Mr. Parshall than he would make for himself. He may possibly be the ablest electric railway engineer of the world, may know everything about a railway from its location and permanent way to the best method of winding its dynamos; but even if he does, it is too much to expect of him or of any consulting engineer that he will not only know all this, but that he also will be able to make complete drawings of an engine such as shall put the British engine builders on a parity with American firms. Mr. Parshall, in his original specifications, shows that he does not wish to accept the responsibility for even the general features of the design of the engine, let alone its complete details, for his specifications as to dimensions are only "suggestions." Even the general form of the engine is not specified, but an "alternative" design is also suggested, and it is also stated that contractors may have the fullest latitude in the use of standard designs. The "issuing of complete drawings in the first instance," therefore, does not seem to have been practicable.

Is there any other course, besides those above mentioned, which might have been taken by the Glasgow Corporation, or which could be taken by others who may hereafter meet similar problems? We think there is, and we will briefly outline it.

If Mr. Parshall could have foreseen all the trouble that has ensued, he might have made a statement to the Tramways Committee, about as follows:

We want four 4,000 HP. engines. No British firm has built electric railway engines of this size, and engines of smaller size are quite different in type, details or proportions from engines built on the Continent and in America. The Allis Co., in Milwaukee, is building both two-cylinder and three-cylinder engines of about this size, and two or three other firms in America, and one or two in Switzerland are also building them, the details of construction, however, differing widely, according to the different ideas of their builders as to how far it pays to go into extreme refinements in order to reach the highest economy of fuel, how strong to build an engine in order to insure it against breakage, and how to proportion bearings in order to insure against heating. Each of these firms is prepared either to build its latest standard form of engine, to build it with some modifications of design which we may suggest, or to build a different engine from complete working drawings furnished by us. If we attempt to make complete drawings it entails great delay, first to reach a conclusion as to the type, form, size and details, and then to execute the drawings; and even when we have made them it is quite likely that our engine will not be as good a one, or as low-priced, as an engine built by one of these firms from its own drawings.

If we ask each of these firms to bid on its standard engine, we are likely to meet trouble and delay. The engine that we may consider best in one sense, say durability, may be the least economical in fuel, and vice versa; and the engine which seems to combine the most advantages with the least disadvantages may be so high-priced as to make its purchase inadvisable. It is very likely that if we receive bids we will feel obliged to reject them all and advertise for new proposals, since not one of the engines bid upon may show the combination of high economy, durability and reasonable price which we desire.

To get around all these difficulties, let us treat the engine-builders as we would architects if we were going to erect a costly public building. Let us ask a few of them, say one in England, one in Switzerland, and two in America (since there are more builders of large street railway engines there than anywhere else) each to submit designs and estimates, for which they will each receive a fair compensation. The consulting engineer for the city will then take these various designs and may either accept the entire design of one competitor and give him the contract to build the engines at his estimate, or he may select features from several designs and specifications and advertise for bids upon this basis.

Of course each competitor will receive general data, such as total power of engines, steam pressure, price of fuel, etc., and he will be asked to present a design which shall make the total annual cost of operation a minimum. The various firms will be asked to furnish only general drawings, giving such information as to form, details and dimensions as may be necessary for the consulting engineers to clearly understand the engine and for comparison with designs furnished by other makers. Together with these drawings, builders will be requested to furnish their usual form of specification, relating to kind and tests of materials, workmanship, finish, etc., and also such written statements as they may choose to submit, giving their reasons for recommending the particular type, form and size of engine shown in the drawings.

The advantages of such a competition to the engine purchaser are numerous. It is sure, in the first place, of getting a number of good designs from first-rate builders. Again, every competitor will present his best design in the hope that it may be adopted, and he will fix a low estimate upon both to influence its adoption and to induce the purchaser to accept his estimate, and give him the contract without further advertising. The purchaser can, if desirable, combine the good features of several different designs, and get thus a better engine for his purposes than that offered by any one of the competitors. He can, if the estimates submitted are excessive, but the designs are satisfactory, obtain bids in open competition from engine builders of all classes. Thus his interests are protected at every point, and at the same time the engine builders are fairly treated, as they are compensated for their work in preparing designs to suit a particular case, and have an open field for fair competition. If anyone can suggest a better plan for protecting the interests of both buyer and seller in this field, we shall be pleased to see it.

Since the above was written, later news concerning the Glasgow engine contracts has come to hand, from which we learn that the Glasgow Tramways Committee has found another solution of the difficulty, and one which seems a fairly good one under the circumstances. On Aug. 28 a conference was held with the four lowest bidders. It was agreed to give the contract to Messrs. John Musgrave & Son, of Bolton, for the four main engines at £95,906, as against £114,564 for the Allis engines, provided that firm would agree to certain conditions as to time of delivery. The Musgraves could not meet these conditions, and at a subsequent meeting it was agreed to accept the offer of Mr. Musgrave to build two of the engines for £24,000 each, delivery in 18 and 20 months, and to give the contract for the other two engines to the E. P. Allis Co. at £28,000 each, one guaranteed to be working in 15 and the other in 16 months. The decision of the Tramways Committee still, at our last advices, awaited the approval of the Council.

LETTERS TO THE EDITOR.

Theory of the Two-Hinged Arch.—Correction.

Sir: In my article in your issue of Aug. 24, I find two of the equations have been incorrectly copied from my manuscript. These are at the foot of page 114 and top of page 115, and should read

$$H = \frac{\Sigma \frac{V\,l\,H}{A} - E\,\triangle L}{\Sigma \frac{h^2\,l}{A}},$$

$$H = \frac{\Sigma \frac{V\,l\,H}{A}}{\Sigma \frac{h^2\,l}{A}}. \qquad (6)$$

The formulas deduced from these are, however, correct as they stand. Yours truly,

Alex. Rice McKim.

106 East 23d St., New York, Sept. 16, 1899.

Wheel Loadings in Computing Bridge Strains.

Sir: The communications of Mr. H. S. Prichard and Mr. J. W. Schaub, in your issues of July 13 and Sept. 7, upon wheel concentrations for railroad bridge design, seem to overlook the fact that the subject is still open for their discussion in the "Transactions" of the American Society of Civil Engineers.

The discussions as published in the Proceedings for August hardly seem to confirm Mr. Schaub's criticism that "two or three members presented some method as a substitute for wheel loads, and two or three more members endorsed it." Mr. Prichard appears to have described the situation more accurately, when he anticipated a lack of unanimity in the choice of an equivalent method. It may be doubted whether a representative committee appointed by the society could make a majority report in favor of any one method. Respectfully,

Henry B. Seaman.

40 Wall St., New York, Sept. 12, 1899.

Mr. Tribe's Book on "Compound Engines."

Sir: I notice your review of Mr. Tribe's book on "Compound Engines," in your issue of Sept. 14, and as it stands your readers will infer from it that the definitions quoted by you were originally published in the "American Machinist." This is not the case, however. None of the definitions given were published by us but have evidently been added to the original matter for publication in book form. I think that the articles as published by us in 1891-1892 will stand criticism, and I have reason to believe that they have been very much appreciated by very many readers. Mr. Tribe has had many years of experience in designing Corliss engines in the original Corliss shops and probably knows a good deal about them, notwithstanding that he is one of those individuals whom your reviewer refers to as a "practical man." Very truly yours,

Fred. J. Miller,
Editor of "American Machinist."

New York city, Sept. 16, 1899.

Power or Hand Brakes for Street Cars.

Sir: The "Cleveland Leader" of this date quotes from your files as follows: "We fully appreciate that for use in crowded streets where the speed is slow and brakes are applied every few seconds, the hand brake has advantages which are exceedingly difficult to duplicate with any power brake." Will you kindly state what these advantages are? Respectfully,

Robt. R. Rifenberick,
Asst. City Engineer.

Cleveland, Ohio, Sept. 9, 1899.

(The main advantages to which we referred are ease of graduation and absolute certainty of action. Watch the motorman running a car in a crowded street and you will see that the brake handle is almost constantly in motion, now to increase the pressure on the brake shoes, and now to ease it off. It is not simply the repeated application and release of the brakes, but their adjustment is continually being altered. Perhaps a power brake can be made which will graduate with equal nicety, but we do not know of any.

In the second place, it is of the first importance that a street car brake shall be always and instantly operative when wanted. Any power brake in which there is a possibility that the power might be absent when called for would be excluded from consideration. In a hand-brake there are, obviously, fewer parts than in any power brake, and consequently less liability to get out of order.

On the other hand, for operating brakes on trains of two or more cars, on very heavy cars or cars run at a very high speed, and for making emergency stops on any cars, the hand-brake is admittedly defective.—Ed.)

Concerning Liquid Air Companies.

Sir: In your issue of this date there is an editorial article, entitled "Concerning Liquid Air Companies," which seriously misrepresents, and is calculated to seriously injure, the American Liquid Air Co. I have the honor of being the President of that corporation, and I therefore ask you to do us the justice of publishing the following reply:

You speak altogether of five companies, and these you divide into two groups, one of which you assert to be characterized by "spending a large amount of money on printer's ink," meaning, thereby, as is obvious from the context, "advertisements in the daily newspapers" and "typewritten letters that are being widely distributed over the country." This group is said to consist of three companies, namely, two Boston concerns and the American Liquid Air Co. The other group, consisting of the Tripler Co. and the General Liquid Air Co., is characterized by you as "not hunting for investors with a brass band;" the inference, of course, being that the American Liquid Air Company is doing so. And after making these distinctions, you go on to hold the "three first-named companies" up to ridicule for not giving "technical informa-

tion" in "their printed publications," for not giving "dates or numbers of their patents," and for giving, "in full measure, claims, promises, offers of stock whose par is $10 at $3 per share, etc.;" the inference here being that such features do not characterize the Tripler and General Liquid Air companies.

This attitude on your part has no justification as regards the American Liquid Air Co. To tell the public that we are on the same level of absurdity as the Boston companies, and that we are of a less honest and reasonable type than the Tripler and General Liquid Air companies, is to say the thing that is not. This you yourself admit in one part of your article, where you state that our "printed matter contains little if anything to which an engineer could take exception." A little enquiry, moreover, would have shown you that our only newspaper advertisement has been a warning to the public against believing that any patent exists of a nature to confer upon any company or person a monopoly of the manufacture of liquid air. You could also have easily ascertained that we have not spent a large amount of money in printer's ink and have not distributed any typewritten letters and have not been hunting for investors with a brass band. What, however, makes your attack on the American Liquid Air Co. particularly unfair is the fact that your article, as regards the really preposterous statements put forward by some liquid air concerns, follows in the wake of an article which I myself wrote in the "Boston Evening Transcript" of July 15, and which was widely read and favorably commented upon in technical circles. I did not hesitate to append my signature to that article, and in it I shrank not from very plain speaking which more than anticipated your own comments. For example, I gave scientific proof of the ignorant folly of various wild statements made by the General Liquid Air Co. and Mr. Tripler; whereas your position is and has been one of virtual endorsement of their absurdities. Turn to your issue of June 8, 1899, and consider the three-page illustrated write-up it gave of the General Liquid Air plant, without a word of warning as to the defects of the apparatus, and without a syllable of comment respecting the statements on the faith of which the company was selling its stock to the public, such as, for instance, that "one gallon of liquid air reduced to its lowest temperature is nearly equivalent for refrigerating purposes to a ton of ice;" that one gallon of liquid air reduced to its proper temperature contains two horse-power per one hour; and that

a single gallon will perform wonders in an ordinary city home. A tumbler-full dipped out and placed in the ice-chest will maintain a temperature of zero in the refrigerator for twenty-four hours. A quart of it placed in the ventilating apparatus will keep the temperature of the whole house at 60 degrees during the hottest summer day. The remainder of the gallon put into the proper motor with an electric dynamo attachment will generate enough heat to do the cooking, run the electric lights, warm the water for the bath, and in the winter heat the entire house by electric radiators.

You may say you did not endorse these monstrous assertions. I reply that silence gives consent, and that your write-up of the General Liquid Air Company's plant was by the public understood to be at least an assurance that in your judgment the company was not based upon a tissue of absurdities and misrepresentations. And the fact of your now publishing another article of an avowedly critical character, in which you pointedly hold up the General Liquid Air Company as being on a higher level of reason and truth than that occupied by some other concerns, will not be regarded by the public otherwise than as a further and well-considered endorsement of its prospectus.

The same remarks apply mutatis mutandis to the case of Tripler. The distinction you have made in his favor warrants the inference that you support him in his claim of being able to produce ten gallons of liquid air by the sole use of three gallons of the same substance plus such atmospheric heat as it can absorb. It also warrants the inference that the Tripler companies give "dates and numbers" of their patents; though I venture to say you cannot mention any United States patent that has yet been issued to Mr. Tripler for any invention in connection with the manufacture of liquid air.

In conclusion and by way of summing up my protest against your attack, I assert in all seriousness, that the American Liquid Air Company is the only concern of the kind that can substantiate all the statements put forth in its printed matter and that has a well-founded assurance of practical and permanent success.

For your further information, I send you a little pamphlet, entitled "The Truth about Liquid Air," in which I have reprinted the "Transcript" article and other criticisms; and I shall be very pleased to furnish a copy of the same (free of charge) to any of your readers who may care to apply for it.

Your obedient servant,

Stephen H. Emmens.

1 Broadway, New York city, September 14, 1899.

(We must decidedly dissent from our correspondent's unwarranted "inferences," as to the position of Engineering News. Our editorial was written to warn investors against the purchase of the stocks of any and all liquid air concerns at the present time, except on the strength of disinterested expert advice, and this warning was explicitly and plainly given.

Concerning Mr. Tripler's apparatus, it is true that Engineering News was the first journal to describe it in detail; but in our description we gave also all the information then available as to the work being done by English and German inventors in the same field. Our correspondent's "inference" that we support Tripler in his famous claim to multiply power by the use of liquid air strikes us as just a trifle absurd, in view of our published comments upon the preposterousness of that claim. We may add that this claim was not publicly made by Mr. Tripler, so far as we are aware, until long after our description of his plant. With all his absurdities, Mr. Tripler has done more than any other one man, so far as we at present know, to advance the art of liquid air production; and he deserves credit therefor. Because no patents have been issued in his name it does not necessarily follow that he has not rights as an inventor that he can maintain, and we think it entirely probable that a long and very expensive battle in the courts and in the Patent Office will be fought before the question of priority is settled between the various inventors who have been working in the field of the liquefaction of gases. This is one reason for our advice to liquid air investors: "Don't!"

Turning now to the General Liquid Air Co.: We described their plant purely as a matter of general interest, and we expressed no opinion whatever as to the merits of its design, or of its scheme as a financial enterprise. Such an expression would have been superfluous, it appeared to us, as the company had its complete plant ready for operation, and any investor could see for himself whether the plant could do what its designers claimed for it or not. We understand that the plant as erected has been unsuccessful. Whether it can be so modified as to operate successfully remains to be seen. As to the preposterous claims for liquid air which our correspondent alleges this company to have made in the endeavor to sell its stock, this is the first time they have been brought to our attention. We have furnished a proof of the above letter to the General Liquid Air Co., and they make their own reply upon this point in a letter printed below.

In conclusion, we have examined the pamphlet to which our correspondent refers, and advise any of our readers interested in the subject to take advantage of his offer to send copies gratis. The author points out that the theoretical refrigerating effect of liquid air is less than 1½ times that of an equal weight of ice, pound for pound, while he gives as its theoretical power storing capacity 1,500,000 ft.-lbs. per gallon, or ¾-HP. hour, which figures agree very well with those which we presented in our issue of April 14, 1898. We may add the caution that the pamphlet's sanguine utterances respecting "the vast opening for the new industry in the tropics" appear to us to be contradicted by its author's own and correct statements respecting the small refrigerating power of liquid air.—Ed.)

Sir: We are in receipt of the proof of a communication addressed you by Stephen H. Emmens, commenting upon an editorial which appeared in your columns last week, intended, doubtless, to warn the public from investing in liquid air stock without first making a proper investigation in the premises.

We in no way except to your article as published; on the contrary, we endorse the same, and have to say with reference to Mr. Emmens' strictures upon ourselves that we attach little importance to them. We are ready to stand for any sins of commission or omission with which any person can properly charge us.

Some time ago, when but little was known by the public, practically, upon the subject of liquid air (none having been made in this country except by Mr. Tripler), The General Liquid Air & Refrigerating Co. issued a prospectus, prepared by an advertising writer who did not have technical knowledge upon the subject. This prospectus was compiled from such evidence as he could obtain, and which he thought reliable, and the clause to which Mr. Emmens takes exception was not a statement of the prospectus at all—it was taken verbatim from the New York "Journal" of April 3, 1898, as having been made by Charles E. Tripler, and he was a person supposed by all to speak with authority on the subject. The error as to the refrigerating power of liquid air was the result of a mistake, which caused the immediate withdrawal of the prospectus from circulation as soon as it was discovered. No stock was sold upon the statements of the prospectus, to anybody, and nearly all the money that the company has had (and it is a large amount) was invested by the officers and directors thereof. This company has not offered any stocks save a sufficient block to build its plant; every dollar received therefor has gone into the construction of this plant, and it is not offering any now at any price.

We will say further that it has invested $50,000 in the establishment of an experimental plant and has conducted its investigations upon a scale which has secured for it a wide commendation from all persons interested in the question of liquid air for purposes of social utility. It is now engaged in this important work, with a faith and earnestness fully warranting the credit given it by your journal and others of like high character. It has United States patents Nos. 621,536 and 621,537 upon an apparatus and method for liquefying air, and it has numerous other patents pending, the claims of which have been allowed. These patents have been duplicated in foreign countries and have actually been issued to the company. This corporation stands exactly where your journal put it as a public institution, subject to the investigation, complete and absolute, by attorney, engineer and expert, of any person who may seek to do business with it.

Very respectfuly yours, Moriz Burger,
Vice-Pres. of the General Liquid Air & Refr. Co.

New York, Sept. 19, 1899.

Sir: It seems to me that every engineer owes it to the community at the present time to do what he can to prevent the consummation of the liquid air swindle, which is now in course of perpetration. This obligation is enhanced by the fact that it is so easily performed. A very few words are sufficient to clear away the fog in which the subject is purposely mystified and make the utter absurdity of the imposition clear to every person of common intelligence.

If a man were to give me a pint of liquid air, he would place me in a position for obtaining power incomparably inferior to that in which he would place me by giving me a pint of water.

No power resides in either the one or the other. Power is obtained solely from heat. The process by which it is obtained is the conversion of atomic motion (which is heat) into dynamic motion. Water is the most common medium for effecting this conversion, and liquid air is the most preposterous.

Neither can be of any use as a medium for the conversion of heat into work, until it has passed into the gaseous state. Both water and liquid air have a strong tendency to evaporate, or to pass from the liquid into the gaseous state, and both do this just as fast as the heat of gasefication can be abstracted by them from surounding bodies.

This conversion under ordinary conditions is, however, exceedingly slow. We are therefore obliged to put water into a boiler, and accelerate the process by the application of furnace heat. Thus we enable the water to assume the gaseous state in which we can apply it to the desired use. By its expansion it then puts other bodies in motion, parting with an equivalent portion of its heat, and partially returning to a fluid.

Now this is the only way in which liquid air can be utilized for this purpose. We must boil it under pressure. It must first of all be put back into the state in which it was. The heat of gasefication which it contained, which has been abstracted from it and thrown away, must be restored. After that the addition of more heat will enable it to do work.

It has always been claimed for air, and claimed correctly, that it possessed the great advantage over water as a medium for the conversion of heat into work; that it does not need to be changed from a fluid to a gas; it is a gas already. It does not need to have the heat of gasefication imparted to it; it contains this heat already. This is true, and if no other condition needed to be taken into account, air would for this reason be universally employed instead of steam in the development of power from heat. The effect of liquefying air is to rob it of this advantage. The one thing that we must have for conversion into work is heat. This preparation of air for use consists in throwing away the heat which it contains and giving us a fluid at a temperature nearly 350° below the freezing point of water.

I am well aware that this is all familiar to your readers, being the A B C of thermodynamics. My object in writing it is to contribute to what I hope may be a general movement on the part of the engineering profession to popularize this truth sufficiently to head off this ingeniously planned scheme of highway robbery.

Chas. T. Porter.

Montclair, N. J., Sept. 16, 1899.

(If it is the duty of engineers to expose swindling enterprises in the engineering field, how much more is it the duty of the public officials responsible for the enforcement of law to stop the depredations and punish the crimes of those who obtain money under false pretences? And yet how seldom is this accomplished! We have exposed many such swindles in the columns of this journal, and have been the means of debarring some from the use of the mails, and winding up the operations of

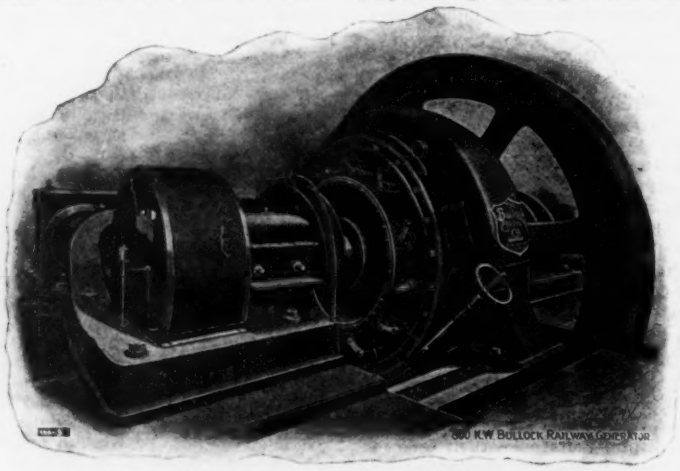
others; but we do not now recall a single case where one of these robbers—it is well to call things by their right names—has been put behind prison bars. So long as crime of this sort goes wholly unpunished, so long will men of the type of Tigg Montague, Esq., in Dickens' "Martin Chuzzlewit," continue to reap fortunes at the expense of the poor and ignorant.—Ed.)

Notes and Queries.

Referring to the article in our issue of last week describing the failure of the Chicago "Coliseum," a correspondent points out that the concrete piers carrying the feet of the arch ribs were flat-topped piers and not skewbacks, and, also, that the concrete roof and the concrete gallery floor would have furnished additional longitudinal bracing between the arches when the building was completed.

A NEW STREET RAILWAY GENERATOR.

The 800-K-W. railway generator shown herewith is notable as marking the advent of an independent manufacturer into the field of production of large-size electrical machinery, which has for some time been monopolized by the two great electric corporations. Claims are also made by the makers for some meritorious features in the design of the machine. A mechanism is provided for moving the brushes slowly back and forth in a direction parallel to the shaft, thus constantly changing the path of travel of the brushes over the commutator face and avoiding any tendency to cut or groove the latter. Such a device is necessary in a direct-connected machine like the one under consideration, where no longitudinal movement of the shaft can be permitted. There is always some end play to the armature of a belted generator, and rotary transformers are sometimes supplied with a magnetic device on the end of the shaft to secure the same result.



800-K-W. ENGINE-TYPE STREET RAILWAY GENERATOR.
The Bullock Electric Manufacturing Co., Cincinnati, O., Manufacturers.

As the pole pieces and coils may be removed without disturbing the yoke or armature, the latter may be repaired while in place. The armature coils, which are thoroughly insulated before being placed on the core, are made of continuous bars of copper without joints between the commutator connections. Slots in the core, perpendicular to the shaft, provide for ventilation.

The 800-K-W. machine shown in the engraving operates at a speed of 80 r. p. m., developing 550 volts at no load, and is over-compounded 50 volts for full load.

We are indebted to the Bullock Electric Mfg. Co. of Cincinnati, the makers of the machine, for the above particulars concerning it.

THE CUNARD STEAMSHIP CO., says a news item, has contracted with the Clydebank Shipbuilding Co. to construct an Atlantic liner 15 ft. longer than the "Oceanic," or say 719 ft. over all.

THE NEW NAVAL POWDER MILL, near Indian Head, will commence making smokeless powder in two or three months. About 1,200 men are now at work on the buildings, about one dozen buildings are up, the electric and water plants are installed, and about as many more buildings are under construction. The capacity of the plant will be 2,000 lbs. of smokeless powder daily. The buildings are widely scattered to avoid the danger from explosions; but a very complete trolley-car system will keep the material moving between them. Commander Cowden, U. S. N., is in charge of the mills.

THE BERKELEY UNIVERSITY, in California, as the result of an international competition, is to be built upon the plans of E. Benard, of Paris, and he will receive the first prize of $10,000. The second prize of $4,000 goes to Howell, Stokes & Hornbostel, of New York; the $3,000 prize to Despardelles & Stephen Codman, of Boston; the $2,000 prize to Howard & Cauldwell, of New York, and the fourth prize of $1,000 is awarded to Lord, Hewlett & Hull, of New York. The money to build the University will be provided by Mrs. Phebe Hearst, the widow of Senator Hearst.

AN EXPERIMENTAL TEA GARDEN is to be established by the Department of Agriculture, and Mr. Elwood Mead, M. Am. Soc. C. E., and State Engineer of Wyoming, will be placed in charge. Supplemental irrigation is to be tried in tea culture, and Mr. Mead will have associated with him Mr. Chas. U. Shepard, who has been experimenting for ten years in tea-raising at Pinehurst, S. C. About one acre of ground has been under cultivation, with 900 tea plants in good bearing. From this garden, Mr. Shepard obtained 56 lbs. of green tea in 1892, and 1,200 lbs. in 1898; from the latter amount, 300 lbs. of standard commercial tea was obtained. On the scale of Mr. Shepard's experiments, the profit was 10 cts. per pound, or about $40 per acre; it is believed that by irrigation this profit could be made $100 per acre in larger plantations. Irrigation is to be tried with the purpose of producing the water supply conditions obtained in Oriental tea-growing countries, applied especially in the period from May to September. The gardens will probably be established at Pinehurst, S. C.

BOOK REVIEWS.

A PRACTICAL COURSE IN MECHANICAL DRAWING.—By William Fox, M. E., Assistant Professor of Applied Mathematics, College of the City of New York, and Charles W. Thomas, M. E., M. A. S. M. F., Instructor in Descriptive Geometry and Drawing, College of the City of New York. With numerous illustrations. New York, 1899: D. Van Nostrand Co. Cloth; 8 × 5½ ins.; pp. 98. $1.25.

This course is especially adapted to the needs of high schools, schools of apprentices and young mechanics. The authors have therefore aimed to make it as simple and practical as possible, to avoid abstract matter and to follow the plan of thoroughly illustrating one thing at a time. The principles are largely taught by the use of models of familiar objects, passing from the simpler to more complex forms. The pupil is taught to handle his drawing instruments and to care for them; to properly dimension and letter his work—and, in fact, to produce a working drawing that clearly gives all the information required from it. The text is clear, without mathematics or the usual geometric introductory to the art of mechanical drawing.

MUNICIPAL PUBLIC SERVICE INDUSTRIES.—By Allen Ripley Foote. Chicago: The Other Side Publishing Co. Cloth; 5½ × 8 ins.; pp. 337. $1.

Mr. Foote is one of a very small group of writers on the corporation side of the municipal ownership question. Although remaining steadfast on the main point at issue, even he is impressed, and the tenor of his writings has been changed of late, by the strong tide in favor of municipal ownership which is sweeping over the country.

Reduced to its simplest form, Mr. Foote's position is that if the rates to private consumers were based on the actual cost of service, instead of placing some of the cost on the taxpayers, rates would be higher under public than under private ownership. He bases this conclusion on the assumption that justice to the taxpayers demands that cost of service should include interest on the whole investment, regardless of the amount of bonds outstanding, a bond sinking fund, insurance against loss by accidents and against "impairment of investment," municipal taxes relinquished and state tax paid (the latter to be provided for by law if not required already), and operating expenses. Private works would base their cost of service on the same items, adding "legal profit" to the interest on investment. This "legal profit," however, would be more than offset by the fact that, according to the author, salaries, wages, material and sundries, comprising operating expenses, would cost more under public ownership. The author cites scarcely any actual figures in support of his arguments.

Some of the best points made in the book are the great need of better systems of accounting in principle and method, and of a uniform system of accounting, for both public and private works, in order that comparisons may be made more readily. He also believes in the necessity of municipal regulation of works under private ownership.

Finally, it is to be noted that the book is not a connected discussion of the subject, but a collection of papers read before various bodies.

WEATHER TABLE FOR AUGUST, 1899. (Furnished to Engineering News by the Department of Agriculture.)

	Stations.	Temperature. (Degrees Fahrenheit.)				Wind.			Precipitation—Rain or melted snow. (Inches.)		
						Velocity in miles per hour.		Direction at time of max. velocity.			
		Average.	Max.	Min.	Range.	Average.	Max.		Total.	Heaviest in 24 hours.	No. of rainy days.
Northern Cities.	Northfield, Vt.	64.5	92	36	56	7.4	27	NW	0.77	0.28	5
	Portland, Me.	65.5	87	51	36	6.0	19	S	1.66	0.40	10
	New York City	73.6	91	60	31	9.1	64	NW	3.90	2.24	8
	Pittsburg, Pa.	74.2	96	55	41	5.6	35	SW	2.57	0.84	7
	Chicago, Ill.	73.5	91	63	28	13.8	54	NW	0.91	0.30	5
	Omaha, Neb.	76.9	95	60	35	7.2	42	NE	6.18	2.88	10
	St. Paul, Minn.	72.0	96	56	40	6.9	32	SW	2.80	0.70	13
	Duluth, Minn.	64.8	82	51	31	8.8	35	NE	6.18	1.88	13
	Bismarck, N. Dak.	67.0	92	43	49	9.7	34	E	0.97	0.57	6
	Average.	70.2	91	53	38	8.1	38	—	2.88	1.12	9
Southern Cities.	Washington, D. C.	74.8	96	58	38	5.4	42	NW	3.77	1.33	13
	Louisville, Ky.	79.2	98	63	35	2.6	50	N	2.72	0.88	9
	St. Louis, Mo.	81.1	98	64	34	7.2	39	NW	2.77	1.28	7
	Savannah, Ga.	83.0	100	67	33	8.2	44	NE	9.04	3.24	14
	Kansas City, Mo.	79.4	100	64	36	7.3	44	NW	5.20	2.10	11
	Jacksonville, Fla.	82.8	98	69	29	7.2	32	SW	3.90	1.36	12
	Chattanooga, Tenn.	80.8	97	66	31	5.7	42	NW	2.39	1.26	11
	New Orleans, La.	83.6	96	71	25	6.6	31	NW	2.31	0.79	12
	Memphis, Tenn.	82.6	97	67	30	4.2	32	NE	2.08	0.85	7
	Palestine, Tex.	83.6	108	67	39	5.6	28	NE	1.83	1.29	4
	Average.	81.1	99	66	33	6.0	37	—	3.60	1.44	10
Western Cities.	Helena, Mont.	60.7	86	41	45	7.1	43	SW	1.26	0.38	11
	Port Crescent, Wash.	54.5	69	39	30	4.6	20	SW	1.40	0.60	10
	San Francisco, Cal.	58.3	78	50	28	14.4	39	W	T	T	0
	Salt Lake City, Utah.	69.8	91	46	45	6.6	32	W	1.06	0.89	3
	Santa Fe, N. Mex.	68.7	87	53	34	5.6	32	S	0.36	0.11	8
	Denver, Colo.	71.9	94	51	43	7.5	43	SW	1.78	1.32	7
	Yuma, Ariz.	—	—	—	—	—	—	—	—	—	—
	Average.	64.0	84	47	38	7.6	35	—	0.98	0.55	7

THE REPORT OF THE NICARAGUA CANAL COMMISSION.

In its issue of Sunday, Sept. 10, the New York "Journal" published the "full report" made to the President by the Walker Commission on the Nicaragua Canal. While all of this work is to be gone over by the new and larger Commission lately appointed, the material gathered and the conclusions arrived at by Admiral Walker and his associates are interesting to all engineers, and we very fully abstract the "Journal's" reprint of the report, as follows:

The Commission here reporting was made up of Rear Admiral John G. Walker, U. S. N.; Prof. Lewis M. Haupt, M. Am. Soc. C. E., and Col. Peter C. Hains, Engineer Corps, U. S. A., thus representing the Navy, the Army and Civil Engineering. The Commission was appointed under the law of June 4, 1897; held its first official meeting on July 20, 1897, and sailed for Nicaragua with a corps of about 100 engineers, etc., on Dec. 5, 1897. The Commission arrived at Greytown on Dec. 17, and remained there until Jan. 5, 1898; it then spent five days in examining the San Juan River, by steamer, and arrived at Fort San Carlos on Jan. 13, and at San Jorge the next day. The Commission then proceeded to Granada and Managua to pay its respects to the President of Nicaragua; and about Jan. 19, it arrived at Rivas and established its headquarters there. Until Feb. 13 was spent in examining the line between the Lake and the Pacific, and the Commission then went to San Carlos again and landed at the proposed site of the Ochoa dam on Feb. 14. After examining this ground the party started on foot over the trail leading across the Divide cut, and finally arrived at Greytown on Feb. 21. On Feb. 27 the Commission left Greytown for Port Limon, Costa Rica, and proceeded to San Jose to pay its respects to the President of Costa Rica; they returned to Port Limon, and, on March 3, sailed on the U. S. S. "Newport" for Colon, and spent five days in going over the Panama Canal route, and the plans, etc., in the Panama Canal office. On March 10 the "Newport" returned to Greytown, and on March 26 the Commission sailed for the United States, leaving its working parties in the field under the direction of Mr. E. S. Wheeler, the Chief Engineer in charge. The last survey party left Nicaragua on Feb. 18, 1899, leaving 13 men in the country, at 10 stations, to continue observations on rainfall, evaporation, lake and river gaging, etc.

As to the physical features of the Isthmus and their adaptation for the best location of a canal, the investigation shows that in early geologic times Lake Nicaragua was an arm or bay of the Pacific Ocean; while the Continental Divide traversed the Isthmus to the eastward, near Castillo Viejo, and the Rio San Juan had no existence as an outlet to the Lake. This is attested by the remains of an old river channel of large dimensions crossing the Western Divide and forming the first outlet for the Lake, after it became separated from the Pacific Ocean; an old drainage channel is also traceable under the present San Juan, west of Castillo, which has gradually filled up with alluvium to the present bed of the stream, with little rock in this part of the river. As a result of the closure of the western outlet and the elevation of the Lake to a mean altitude of over 100 ft. above sea level, the outflow was finally diverted to the eastward over a depression in the original divide.

The water supply problem is thus set forth, as far as observation, surveys and measurements, will permit:

Area of water surface of Lake Nicaragua (2,000,000) acres, sq. miles	3,000
Approximate area of entire drainage basin, sq. m.	12,900
Maximum dimensions of Lake Nicaragua, 101 by 45 miles.	
Elevation of Lake Nicaragua, 98 ft. to 111 ft., mean 104½ above M. S. L.	
Elevation of Lake Managua (above Nicaragua), approximately, 28 ft.	
Area of Lake Managua, square miles	438
Length of Rio San Juan 121.7 miles.	
Extreme range of temperature on line of canal for 1898 (65° to 96°)	31°
Maximum rainfall observed at Rivas was in 1897, when it was	123.43 in.
Minimum rainfall observed at Rivas was in 1890.	31.81 in.
The average rainfall on the basin for 1898 is found to be 28% less than that at Rivas.	

Lake Nicaragua is described as shoaling near the outlet to such an extent as to require considerable dredging in soft material, with no rock near the channel. The principal island, containing the cones of the extinct volcanoes Ometepe and Madera, rises over a mile above lake level and affords an excellent harbor to leeward, convenient for anchoring. Thirty sq. miles of the lake extends below sea level. The lake is separated from the Pacific by a strip of land about 12 miles wide, with a range of traversing hills varying in elevation from 155 ft. to more than one mile above sea level. The Pacific harbor, at Brito, is made by a bold, rocky promontory, 248 ft. high, covering a natural bight in the coast and affording "an admirable site for an artificial entrance and harbor." The streams on this side are small, with limited drainage, and are nearly dry five months in the year. But the slope of the Rio Grande is steep, falling about 120 ft. in less than 11 miles.

The topography of the valley is, however, well adapted to the purposes of a canal on either bank, or to the creation of an artificail basin by a dam closing the gorge through which the lake drainage formerly passed to the sea.

The rocks on this division are sedimentary and readily worked, being loose shales and sandstones with traces of calcium. The material composing the coastal plain is a light, sandy loam, and easily eroded.

The country traversed by the San Juan may be conveniently divided into two sections, to wit: That portion lying above the confluence with the San Carlos, in which the deposit of sediment is relatively small, and that below, in which it is large. Further subdivisions are suggested by the topographic conditions.

From the lake to the first rapids, at Toro, 27 miles, the slope is gentle, being about 2½ ins. per mile, while the banks are low and the adjacent swamps extensive. From the head of the Toro to the foot of the Machuca, embracing the four rapids, the fall is nearly 43 ft. in 23 miles, or 22½ ins. per mile. This comprises the rocky section of the ancient Continental Divide, and is the gorge of the river valley.

Below Machuca occurs a stretch of about 15 miles of deep water, the bottom of which extends in places below sea level, known as the Agua Muerta (dead water). This is a portion of the old river channel not silted up by the volcanic sands brought into the Lower San Juan by the San Carlos River.

This sand becomes a characteristic feature of the entire lower reach of the river and its delta from this point to the sea. It is confined, however, mainly to the bed of the channel, the banks through the hill country being the stiff clays resulting from the weathering of the rocks of the region.

These banks are remarkably stable, notwithstanding the heavy rains and large volume of water which sweeps past their bases at high stages.

As the bend of the upper river forms an important part of the route, a more detailed description of it is believed to be necessary. The slope, as given by the survey and corrected for stage, may be stated to best advantage in tabular form. This, taken with the cross-sections, velocity and volume of discharge, as stated in detail in the accompanying reports of the assistants, will show the characteristics of the streams in a state of nature.

The Upper River.

Reach.	Distance, miles.	Fall, ft.	Rate of fall per mile, ft.
From the lake to Sabalos	27.16	5.4	0.198
Sabalos to foot of Toro Rapids	1.70	7.3	4,294
Toro to head of Castillo	7.98	1.2	0.150
Castillo to bottom of rapids	0.38	6.0	15,789
Castillo to head of Balas Rapids	2.08	2.5	1,202
Palas to one mile below Machuca	10.62	26.0	2,448
Machuca to Boca San Carlos	14.79	1.0	0.067

The Lower River.

San Carlos to San Juanillo	33.02	30.0	0.908
San Juanillo to Colorado	5.28	4.0	0.757
Colorado to sea (via San Juan)	18.65	21.0	1,128
Lake to sea	121.66	104.4	0.86 av.

The slopes are, however, constantly varying with the stage and local conditions. A heavy rainfall on the San Carlos basin may reverse the slope for a time in the Agua Muerta, causing the water to run up stream.

At Sabalos, where the slope is about 2½ ins. per mile, the maximum velocities and discharges as observed were reported as follows:

	Cross section in sq. ft.	Mean velocity, ft. per second.	Discharge, cu. ft. per second.
Jan. 21, 1898	8,819	2.16	19,000
Feb. 21, 1898	8,576	1.92	16,530
Sept. 11, 1898	11,273	1.95	21,995
Sept. 14, 1898	10,684	2.12	22,673
Sept. 21, 1898	10,720	2.09	22,431
Dec. 3, 1898	11,273	2.39	26,700

In the upper reaches, the slope being very flat, the river carried over 20,000 cu. ft. through sections of over 10,000 sq. ft. at velocities exceeding 2 ft. per second, with corresponding increase at the gorges and rapids.

At Ochoa Station, about 60 miles from the lake, the banks are steep clay slopes. The bed of the river consists of black sand of the same character as that composing the sea beach near Greytown.

In a state of nature the mean velocity of the stream is frequently over 4 ft. per second, and at times exceeding 5, while the lower river discharges over 50,000 cu. ft. per second, and occasionally over 100,000, with perceptible effect upon the banks.

The slopes of the stream, therefore, vary from about 1 in. per mile in the Agua Muerta to 6 ft. in one-third of a mile on the Rapids of Castillo, and the velocity from less than 1 ft. per second to over 12, while the recorded discharge at Ochoa ranges from 16,145 to 104,930 cu. ft. per second.

To pass the Castillo Rapids at low stages of the river a tramway has been constructed under the brow of the hill for the purpose of transferring passengers and freight. The width of the upper river is quite variable. It ranges from about 350 ft. to 1,200 ft.

Its general alinement is direct, but there are several sharp horseshoe curves where cut-offs would be required across alluvial flats, by which over five miles of distance would be saved.

The principal tributaries from the Costa Rican side are the Rio Frio, Poco Sol, San Carlos and Sarapiqui, the former emptying into the lake just at the head of the river. These large streams exert a controlling influence in confining the location of the canal to the left bank.

The streams on the left bank are the Melchora, Palo de Arco, Negro, Sabalos, Machuca, La Cruz, Machado, Danta, San Francisco and others, none of which has a large drainage basin. They have many small branches permeating the swamps and ravines which characterize the broken topography of this section.

On reaching the edge of the coastal plain the river drainage is distributed through the San Juanillo, Colorado, lower San Juan, Taura, and their branches, Parado and Cano Bravo, leading to the sea.

The minimum computed discharge of the upper river at the Sabalos station during 1898 was found to be 11,206 cu. ft. per second on May 13, while the maximum occurred on Nov. 13, when it was 28,480 ft., the difference in stage being 3.55 ft.

At Ochoa, below the mouth of the San Carlos, the minimum computed discharge on March 10 was 16,300, and the maximum was 107,000 cu. ft. per second on Nov. 17, the variation in stage being 13.35 ft.

To provide for extreme cases, however, it is estimated that the river above the San Carlos may, at rare intervals, under the cumulative discharges from the lake and river, reach a possible maximum of 100,000 second-feet, and that the San Carlos, a flashy and torrential stream, may add 100,000 more to this quantity in the lower section for a short time.

The entire river bed has been carefully surveyed, with a view to determine its carrying capacity under the regimen resulting from the creation of such dams and locks as may be found best adapted to convert it into a navigable channel for deep draft vessels.

The upper river will require dredging from the lake to the Castillo Rapids, and as the channel as proposed will be 300 ft. wide at bottom and extend to a depth of 30 ft. below the lowest lake level, this cut will largely increase the cross-section and thus enable a larger volume to be discharged without any material increase of velocity.

Moreover, the river falls about 13.9 ft. below the 105 stage in the lake before reaching the head of the Castillo Rapids, so that a dam farther down stream impounding this water would still further augment the cross-section by raising the surface. As the capacity is regulated by the smallest sections it is necessary to ascertain their location and effects upon the discharge under the new regimen.

Under existing conditions the ruling sections of the stream are found to be at the head of the Toro Rapids and Castillo Rapids in that section of the upper river between Port San Carlos and the Castillo Viejo.

It appears that the location of the controlling section would be changed from its present position to a point five miles from the lake, while the area of that section would be very nearly doubled at a lake elevation of 110 above tide.

As the maximum discharge required to pass through this section, with a range of 6 ft. for the greatest fluctuation, would not produce velocities exceeding 3.3 ft. per second, such a discharge would not materially affect the stability of the channel nor its navigation.

Instead of having velocities exceeding 12 ft. per second over the rapids, which would be submerged, the maximum current in the river under a discharge of 30,000 cu. ft. would not exceed 2 ft., or 1½ miles per hour, which would not readily disturb the banks of this section of the stream. Under ordinary conditions and throughout nearly this entire reach the velocities would be less than 1 ft. per second.

With a discharge of 50,000 cu. ft., which is higher than will probably ever be reached in this (upper) part of the river, the maximum velocity through the controlling sections would not, therefore, much exceed 3 ft. per second, imposing no material restrictions on navigation.

So much stress has been laid upon the excessive precipitation and its destructive effects upon the proposed works, as well as upon the labor and machinery, required, that the Commission is impelled to call attention to the fact that the physical features of the country furnish the most convincing and conclusive evidence that these un-

controlled forces are not so injurious as has been alleged, for the angle at which freshly made earth slopes stand is found to be much steeper than that prevailing in our more northern latitudes, where they are also exposed to the destructive action of frost and the internal stress due to greater range of temperature.

In some cases in the northwest the range covers 101°, whereas in Nicaragua the greatest fluctuation seldom exceeds 25°. The absence of frost more than compensates for the excessive downpour.

Nature compensates for the greater rainfall by the uniformity of heat and moisture. The spontaneous growth of vegetation protects the natural surface, clothing it with a protecting thatch, which not only acts as an elastic cushion to break the impact, but also to retain the water, and thus prevent the sudden and destructive floods so familiar to us during the spring.

The Commission believes that the risks from disease is slight; as the natives suffer little from fevers, and it has been proven that Americans can preserve their health, even in passing directly from a vigorous winter to the mild regions of the trade winds.

The narrow limits within which the temperature ranges is shown from a few selected observations at various stations during the year as below. The Rio Viejo station is located on the western slope of the Cordilleras east of the lake and at a higher altitude than the others. Hence its greater range of 30°:

Exhibit of Extreme Range of the Observed Temperature in Nicaragua.

Date, 1898.	Station.	Maximum. °F.	Minimum. °F.	Date, 1898.	Range.°
Dec. 22	Brito and Tola	88	75	June 28	13
May 12	Las Lajas	91	73	Sept. 10	18
Mar. 3	Rio Viejo	97	62	Mar. 12	35
May 8	Fort San Carlos	91	70	Mar. 28	21
Mar. 20	Sabalos	95	65.2	Dec. 25	24.8
May 7	San Carlos River	95	66	Feb. 7	29
Oct. 1	Ochoa	95	66.5	Jan. 3	28.5
May 25	Deseado River	91	65	Jan. 3	26
Sept. 29	Greytown	96	69	Mar. 14	27

From the most reliable data obtainable, the Commission is of the opinion that the canal region is "practically exempt" from any seismic influence of sufficient force to destroy or even endanger any part of the canal route. Under this head it refers to the reports of Dr. C. W. Hayes and Major Dutton—The Materials of Construction—earth, rock, timber and sand, are all abundant and free. Dr. Hayes says that the alluvium is everywhere of such a character that it can be easily handled with dredges; and almost everywhere the silt and clay-silt will stand at moderate slopes. This material becomes very hard when dry, and he thinks that when the canal is more than half in excavation, the silt will form banks sufficiently impervious to hold the required height of water without the addition of other material. The black volcanic sand of the east coast and lower river section should make a good mortar; it has a specific gravity of 1.68, or 104 lbs. per cu. ft. Excellent clay is abundant and well distributed. Much of the timber is denser and stronger than American oaks and pines, and will last 40 to 50 years above ground.

Iron and steel will necessarily be imported, but the climatic conditions are such as to cause remarkably little deterioration. Templates of the rails which have been exposed to the rain and sun for about nine years do not exhibit any measurable loss in section of weight.

Only where the salt water of the ocean reaches the iron rails and bolts on the pier is there any considerable amount of scale visible.

Sandstone of average quality is found in heavy beds near Brito, and it would probably yield a good quality of dimension stone, up to 20 ins. thick. North of the canal line, at Buena Retiro, is a large deposit of trap-rock, suitable for structural purposes. The principal varieties of igneous rock, on the Eastern Divide, are—augito-andesite, olivine basalt, hypersthene basalt and dacite; the three first are generally classed as trap-rock, the dacite is lighter and somewhat softer. The sedimentary, or softer rocks, form the larger proportion, and though some of this may require blasting, the Commission considers it as earth, along with aluvium and residual clay.

To provide ample facilities for the safe and expeditious passage of vessels, the trunk of the waterway has been considerably enlarged over that of any previous project. The dimensions adopted by the Commission as the basis of the estimates are as follows:

The canal nowhere to be less than 30 ft. in depth. The width varying with the local conditions as follows: From Greytown harbor to Boca San Carlos the bottom width to be 150 ft., with slopes in earth of 1:1 and in alluvial silt of 1:2. In hard rock vertical sides 40 ft. from the bottom, with slopes 5:1. In soft rocks the slopes to be 2:1.

In the river the width at bottom to be 300 ft., with slopes of 1:2, with enlargements at the bends, and at the eastern end of the lake the excavation to be 600 ft. wide at the outer end, decreasing to 300 ft. at the river, and having slopes of 1:5 to the depth of 6 ft. and then 1:3. For all routes from the Caribbean Sea to the lake, excepting the Menocal route, the same dimensions are used.

The bottom width of the canal from the lake to the Pacific to be 150 ft., with slopes as on the east side, and the computations have been based upon a minimum lake elevation of 104 above mean sea level, Caribbean Sea as a datum. The minimum radius is limited to 3,000 ft., with enlargements of width in bends varying according to the degree of curvature.

The locks are $80 \times 30 \times 665$ between quoins, giving an available length of 630 ft. with variable lifts.

Estimates were also made upon numerous modifications of the above dimensions.

For convenient reference and comparison with the canal prism as proposed by the Maritime Canal Company, the areas of the several cross-sections and the percentages of increase are stated herewith:

Area of cross-section in sq. ft.		% of increase.
Between jetties, Greytown	23,400	..
Entrance to harbor, Greytown	14,700	..
Coastal section	6,300	10.3
Canal proper	5,400	9.1
Through rock	4,500	50.0
In the river (in rock)	9,900	131.0
In the river, (in earth)	10,800	84.0
In the lake	7,272	73.0
	13,272	216.0
West Side.		
Western divide	4,500	50.0
Across coastal plain	5,850	8.0 less

Distances Along the Line of the Canal Route Proposed by This Commission, from the Seven Fathom Curve in the Pacific Ocean to the Seven Fathom Curve in the Caribbean Sea.

		Miles.
1.	Brito Harbor	0.93
2.	Brito to Buena Retiro	8.04
3.	Bueno Retiro to west side of lake	8.71
4.	Lake Nicaragua	71.34
6.	East side Lake Nicaragua to Boca San Carlos	56.96
6.	Boca San Carlos to Saripiqui	21.59
7.	Saripiqui to Greytown	20.59
8.	Greytown Harbor	1.74
	Total	189.90

All plans for a canal by the Nicaragua route contemplate using the lake as the summit level for the canal and as a feeder. The regulation of its level is therefore a matter of the greatest importance.

It is known with reasonable certainty that the lake has varied in its elevation above sea level as much as 13 ft. It has probably been as low as 98 ft. above mean sea level, and as high as 111 ft. above the same plane. These extremes have occurred at relatively remote intervals, but their occurrence in the absence of regulating works must be reasonably anticipated.

It is also known that, notwithstanding the losses due to the outflow through the San Juan River and to evaporation, the lake has risen as much as 2 ft. in six weeks.

The higher the lake is held the less will be the excavation in the upper level, and as this is a heavy item in the cost of construction, the effort has always been to keep that level up as high as practicable, without causing unnecessary damage to private property. On the other hand, a spillway of capacity sufficiently great to prevent the lake from rising is expensive. The problem, therefore, is how best to meet the varying conditions.

The area of Lake Nicaragua, in round numbers, is 3,000 sq. miles, nearly 2,000,000 acres. The drainage area, including both lakes, is about 12,900 sq. miles. During the dry season of 1898 measurements were taken to determine the total inflow into Lake Nicaragua, which was found to be only about 1,700 cu. ft. per second, showing that in the dry season the inflow into the lake is scarcely worth considering. Nearly all the streams showed evidences of being stagnant several months, yet the year 1898 was one of more than average rainfall.

Observations to determine rainfall have been kept at Rivas for the last 19 years. Comparing the records at Rivas for the year 1898 with those for the other points it will be noted that the rainfall at Rivas was greater than the average for other parts of the basin; that at Rivas being 108 ins. and the average in the basin 78 ins., a difference of about 28% in favor of Rivas.

This might at first appear anomalous, but it may be accounted for by the peculiar topographical features of the country in connection with the prevailing winds. It will therefore be assumed that in order to obtain the rainfall in the basin for other years than that of 1898 the Rivas record will have to be reduced by 28%.

There are two distinctly marked seasons in the drainage area of the lake—the wet and the dry. The latter begins about Dec. 15 and lasts until about May 15. The wet season then begins and lasts until Dec. 15 following. It is probable, however, that the length of the wet and dry seasons may vary in some years.

The amount of evaporation as determined for the year 1898 was 52 ins. That year was an abnormally wet one and it is therefore probable that the evaporation was somewhat below the average. Mr. Davis estimates a normal annual aggregate at about 60 ins., or about 5 ft. The amount of evaporation in the lake itself has been taken at 4 ins. per month during the wet period, and 6 ins. during the dry.

These results have been checked by the Commission's study of the exhibits, as follows: It appears that during the year 1898, throughout which careful examinations were made, the lake fell about 3.00 ft. between Jan. 5 and May 15, a period of 131 days, or 4.5 months, while in the following season of rainfall it rose 4.72 ft. by Dec. 5, when it again began falling. The net gain in storage during this entire year from Jan. 5, 1898, to Jan. 5, 1899, was 15.6 ins.

It will be observed that during that portion of the season beginning Feb. 1 and ending May 15 the lake surface declined uniformly, and that in this time the total rainfall did not exceed 2¾ ins. over the lake surface.

The run-off from the parched ground at this season is practically zero. Hence the only gain was the direct rainfall, while the losses were those due to evaporation and outflow.

The outflow between Feb. 1 and May 15 is given as 2,817,748 acre-feet, equivalent to a vertical depth over the lake area (2,000,000 acres) of 1,408 ft. If this be deducted from the loss in storage and rainfall, which is 2.840 ft., it leaves 1,432 ft. loss due to evaporation in 104 days or a diurnal rate of .165 ins., or 5 ins. per month, or a rate of 5.00 ft. per annum for a dry year. This being deducted during the dry season would doubtless represent the maximum for the year.

The run-off or inflow to the lake, from rainfall on its drainage basin, exclusive of the lake proper, for the year 1898, has been found to be about 30% of the rainfall. This is computed as follows:

The average rainfall at six stations in the basin of Lake Nicaragua for 1898 was 78.29 ins. During that year the lake rose 18 ins. The outflow, if held, would have raised the lake 84 ins. Evaporation as determined was 52 ins., so that if there had been no outflow or evaporation the lake would have risen 154 ins. Of this 78.29 was by direct fall on the lake, leaving 75.7 ins. as the rise due to the fall on the land or the run-off.

The area of the lake is 3,000 sq. miles; the area of the tributary basin is 9,900 sq. miles. The latter is, therefore, 3.3 times that of the former. Dividing the inflow into the lake, 75.7 ins., by 3.3, the ratio of the lake surface to the exterior drainage, we have 22.94 ins. as the rise due to run-off. This is 29.3% of the rainfall.

When the canal is built the lake will be drawn upon for water for lockage and for power. There will also be some leaking, the amount depending largely upon the kind of dams and wasteways used. The estimate for lockage is necessarily arbitrary, but a computation based on large traffic through the canal gives 3 ins. as the estimate for annual requirements for lockage, leakage and power.

The surface of the lake is acted upon by several opposing forces. They must be so regulated that its fluctuations can be controlled within proper limits. Evaporation, outflow and use of the canal will lower the lake's level. Rainfall and inflow will raise it.

Water must therefore be stored for evaporation and use, and the excess of rainfall and inflow be discharged. For purposes of storage against evaporation years of minimum rainfall must be considered, and for determining spillway capacity years of maximum rainfall.

The year of minimum rainfall, as determined by the Rivas record, is 1890. During that year 31.81 ins. of rain fell. If this is reduced by 28%, the difference between Rivas and the average of other parts of the basin, we have 22.9 ins. as the average for the basin in an extreme dry year. It is probable that this estimate is too low. Twenty-eight ins. have therefore been assumed as a minimum annual rainfall in the basin.

The estimated run-off for 1898 was 29.3% of the rainfall, and as the run-off will diminish with the diminution of the rainfall, 25% of the rainfall has been taken as the average for a dry year. We then have 28 ins. falling directly on the lake and 28 ins. on the drainage area tributary thereto. The latter being about 9,900 sq. miles, enough water would fall on the land to raise the lake 23.1 ins. This added to that falling direct will raise the lake 51.1 ins. if all sources of loss are cut off.

But the loss from evaporation would be about 60 ins., and 3 ins. would be lost by lockage, leakage and use—a total of 63 ins. or 5 ft. 3 ins. There would then be a deficit of 11.9 ins. at the end of the year. If the year ends with the end of the wet period the succeeding dry period will be begun with this deficit.

For this period, lasting about five months, during which the lake would receive practically no rain, and evaporation would be at the maximum, the loss to the lake would be 30 ins. for evaporation and 1½ ins. for lockage, leakage, etc.; total loss, 31½ ins., which, added to the deficit of 11.9 ins., gives 43.4 ins. as the deficit at the beginning of the wet season, when the lake would probably fill up again.

Temporary storage of about 4 ft. in the lake is therefore needed to provide for evaporation and use in a time covering two dry periods and one wet one. In other words, if the lake had been at 108 at the beginning of the first dry period, it would have fallen to 104 at the end of the succeeding dry period.

In a year of maximum rainfall and minimum evaporation the conditions are reversed. The problem will be to

get rid of surplus water and prevent the lake from rising to a high level. The year of maximum rainfall, according to the Rivas record, was in 1887, when 123 ins. fell. Reducing this by the 28% ratio we have a rainfall in the basin of 89 ins. for the maximum year. As before stated, the variation in annual rainfall over a large area is not as great as it is at one station.

It is, therefore, probable that for the entire basin this estimated rainfall is too great. Suppose it to be taken at 84 ins., or 7 ft. There results:

	Ins.
Rainfall direct on the lake	84
Run-off, 33%, about	84
Total inflow	168
Deduct for evaporation and use	63
	105

This represents what must be taken care of by storage and discharge.

This rainfall will not be extended uniformly over a year, but most of it will fall within the wet season of seven months. A mean discharge of about 40,000 cu. ft. per second would discharge it all at this time. Or, if 4 ft. be stored in the lake, a mean discharge of 22,000 cu. ft. per second would take care of it.

Inasmuch as it is impossible to know in advance whether the rainfall of a season is to be heavy or light, it will not be safe to begin discharging at the full capacity of the outlet until enough water has been stored for possible deficiencies.

Consequently, instead of having seven months' time in which to discharge the surplus, a large part of it might have to be discharged in a less time, and a spillway of greater capacity would be needed. With a spillway capacity of 50,000 cu. ft. per second the entire surplus could be handled in about 92 days.

Chief Engineer E. S. Wheeler makes a special report upon rainfall and computations for dams and wasteways. He assumes the evaporation from the lake surface during the wet season of 164 days to be the same as in 1898, 20.97 ins.; and deducting this amount from 148.58 ins., the estimated rise of the lake due to the wet season's rainfall, leaves 127.61 ins. that must be provided for by outflow or temporary storage. On the 3,000 sq. miles of lake area the 127.61 ins. would amount to 889,408,618,000 cu. ft.; and if this could all run out in 164 days, the mean discharge would be 62,769 cu. ft. per second, and there would be no change in the elevation of the lake surface. But for each foot of fluctuation of surface the required rate of discharge would be as follows:

	Cu. ft. of discharge.
No fluctuation requires	62,800
1 ft. requires	56,900
2 ft. requires	51,000
3 ft. requires	45,100
4 ft. requires	39,200
5 ft. requires	33,300

From all the data secured the Commission concludes that a spillway of 50,000 cu. ft. per second capacity should be provided; and that the lake may vary its level from elevation 104 to 110.

The endeavor would be to approach the dry season with the level of the lake at about 108, and during that dry season to draw it down to 106, if it did not go to that level from natural causes. At the beginning of the wet season the lake would be allowed to rise, but when it reached 108 the spillway would be opened, gradually at first, and at its full capacity if necessary. In this way there would be a margin of 4 ft. for the lake to fall in dry seasons and the same amount for it to rise during wet seasons. This is believed to be ample.

As no suitable location for a spillway could be found on the Pacific side, it was suggested that the surplus water may be discharged through the canal itself as far as Buena Retiro, and there turned into the valley of the Rio Grande, and thence to the sea. But this plan would necessitate a widening of the canal section to Buena Retiro, or for 9 miles, mostly through rock; and further, the discharge of 35,000 to 50,000 cu. ft. per second into the valley of the Rio Grande would create a torrential river, in a light, sandy soil, with a fall of 80 ft. in the 8 miles of its course to the Pacific. The canal itself would be in this valley, and might be endangered. For these and other good reasons, the Commission deems it better to discharge only 15,000 cu. ft. per second of this surplus water down the Rio Grande valley, and discharge the remainder through the San Juan River. It believes there is no danger from erosion in the San Juan.

The Commission then discusses the several canal routes from Lake Nicaragua to the Pacific proposed by Col. Childs, Mr. Menocal and the Commission of 1895. The Commission adopts the Menocal project, but thinks it should be modified by providing a second lock and dam near Bueno Retiro, between the La Flor Dam and the Lake. This would diminish the size and the dam lowered; less land would be submerged and fewer difficulties would be encountered in constructing the La Flor locks. They think the best location for the lock is on the left bank, or east side of the Rio Grande.

The Eastern Division admits of more variants. The Commission deems it impracticable to canalize the San Juan, from the San Carlos River to its mouth, because of the difficulties of securing good foundations for dams; the torrential discharge of the San Carlos and Sarapiqui rivers, and the great quantities of sand carried by these rivers and deposited in the lower San Juan. The Commission describes the high level project of Mr. Menocal, extending the lake level through the divide cut to within 12 miles of Greytown, with a great dam at Ochoa across the San Juan. In this project there are 67 large and small dams and 15½ miles of embankment; and the divide cut would be 3 miles long, with a maximum depth of 350 ft. and an average of 134.4 ft. A third project proposed a dam in the San Juan above the mouth of the San Carlos River, giving slackwater navigation from the lake to the dam; thence by a canal excavated along the left bank of the San Juan to the junction of the San Juan and San Juanillo; and thence across the coastal plain to Greytown. Both this and the Menocal plan could be varied. The Commission says:

Mr. Menocal's project has an advantage in that it is two miles shorter than the other project following the bank of the river.

The disadvantages are:

First—The engineering difficulties encountered in building the Ochoa dam. This dam being located but a short distance below the mouth of the San Carlos River, its construction would be attended with no little risk.

Second—The San Francisco embankment line is another troublesome engineering construction. This embankment follows an irregular line from Ochoa to the Divide.

No less than 67 dams will be required, some of them insignificant in size, but four of them of great length and of more than ordinary difficulty to build and maintain, because of their great height and the pressure of water to which they would be subjected, as well as to the fact that the soil on which they would have to be founded is overlaid for a great depth with soft ooze.

A third disadvantage is the Divide cut itself. This, as before stated, is over three miles long. In addition, it is curved, the curvature being in places the maximum that should be allowed in a canal of this magnitude. This alone would render navigation difficult. Its great depth would also be a constant menace, for while it is believed that the rock for the most part would stand, there is some likely to cause trouble. A large portion of it—dacite, a rock that weathers rapidly—is of light specific gravity, and not to be trusted in a deep cut like that through the Divide.

Again, on account of its depth and length, it would necessarily be made of the minimum width practicable for navigation; consequently, if the canal were working to its full capacity there would inevitably be some delay to vessels passing through it, since two large ships could not pass each other. Vessels would therefore accumulate at either end, to be passed at stated intervals in fleets.

The variant providing for the construction of a lock and dam at Machuca, locking down, say 24 ft., would reduce the height of the San Francisco embankments and the Ochoa dam; but the excavation in the San Juan River and eastward to the eastern end of the Divide cut would be increased by this extra depth.

There would still be the Ochoa dam, though of less height, to be constructed in contention with the floods of the combined San Juan and San Carlos Rivers. If the dam be built above the mouth of the San Carlos River, instead of below it at Ochoa, there would yet remain the objectionable San Francisco embankments and the Divide cut.

The project which looks to the construction of a dam above the mouth of the San Carlos River and follows close to the north bank of the San Juan River as far as the junction of the San Juan and San Juanillo, has the disadvantage of an increase in length of about two miles, but on the other hand it is believed that difficulties of construction will be lessened because of the reduction in the height of the embankments and by avoiding the Divide cut.

There are, nevertheless, several hills of considerable height to be cut through on this route. The Tamborcito hill will require a maximum depth of 230 ft. of cutting in rock, but it is less than a half mile in length and the material will be required on the work, while an attempt to circumvent the hills may involve an embankment founded upon a depth of 80 ft. or more of black sand in the bed of the river.

From this point to lock No. 1 most of the canal trunk will be enclosed between embankments built of the silt from excavations. In short distances they may exceed 30 ft. in height, with a pressure of 20 ft. of water.

A variant on this project would be in the construction of two dams in the river above, the one near the mouth of the San Carlos. But it has no advantage over the other except that it enables the lower dam to be reduced in height. This is not considered of great importance, for while the construction would be easier the main difficulty would be in the foundations, and they would not be materially different.

It has several serious disadvantages, however, in obstructing the passage of large volumes of water at narrow sections of the river and in confining the navigation below the upper dam to a narrow channel excavated in large part through rock. Numerous other adjustments in detail may be made, both in the alinement and grade, but they are not of sufficient importance to warrant consideration prior to final location.

The Commisson believes that Greytown can be made to provide a suitable entrance and a harbor of limited area. A study of the amount of material to be controlled in maintaining the entrance—in moving sands, etc., results in an estimate of from 500,000 to 730,000 cu. yds. annually. The Commisson, therefore, locates the east jetty about 2,000 ft. westward of the position suggested by the board of 1895; the harbor itself to be 5,000 ft. long by 1,000 ft. wide, with 600 ft. between the jetties. As the drift sand accumulates to windward, the jetties must be gradually advanced seaward until the capacity of the receptacle is exhausted. They think the jetties should be built chiefly of heavy stone.

At the Pacific end the Brito harbor must be constructed; but the Commission deems this a comparatively easy engineering task. The plan is to built a jetty from a point on the beach about 3,600 ft. east of the Brito promontory, extending out into the sea to the 7-fathom curve in a nearly south-southwestern direction. The harbor would then be excavated within this, with a 600-ft. entrance at the throat. The basin to be excavated would have an area of about 135 acres and a depth of 30 ft. at mean low tide and 36 ft. at the entrance. The Rio Grande would have to be diverted at its lower end.

The Commission believes that the sites it has selected for dams and embankments, taken in connection with the impounding capacity of the lake, will subject them to little or no danger from sudden floods reaching their crests. In regard to the Ochoa dam, the report says:

In view of the large amount of earth and rock excavation and the necessity for disposing of the spoils, it was decided by the Maritime Canal Company to construct high rock-fill dams on both sides of the lake for the purpose of impounding the waters on the summit level, but the desirability of avoiding the San Carlos River and of facilitating the construction of the dam itself have led this Commission to select a new and better site a short distance above the mouth of the San Carlos River.

The borings made on the site of the proposed Ochoa dam revealed rock at 17 ft. below sea level suitable for foundations. The width between banks is relatively narrow, for at an elevation of 100 ft. above sea level it is about 1,400 ft.

As this site is below the junction of the San Carlos River, which, at flood stages, it is estimated, may discharge 100,000 cu. ft. per second, in addition to the lake and San Juan River drainage, this large volume must either be disposed of over spillways on the San Carlos ridge or be allowed to waste over the dam itself. Its sediment also would be deposited in the bed of the stream above the dam and cause considerable constant shoaling.

At lower Ochoa the sand extends to 30 ft. below sea level. To avoid these serious objections, as well as to eliminate, if possible, the embankments of the San Francisco and Florida lagoons, examinations were made for a dam site at Tambor Grande Island.

The subsequent borings in the bed of the river at this site, however, showed an erosion of the bedrock extending to 128 ft. below sea level, which would necessitate a dam in this narrow gorge of the river nearly 250 ft. in height, subject to the flow of the entire drainage basin. This project was, therefore, discarded.

The more recent examination and surveys made on the wider reach of the river above the San Carlos gave results which were quite satisfactory. Here the flowage line is almost continuous, requiring but one small embankment, while the section affords ample weir length. Good solid rock foundations exist at about 15 ft. below sea level. Thus the maximum height of the dam from the bottom of the foundation would be 138 ft.

The construction of a dam at this point avoids the serious objections to the Ochoa site, and also reduces the cost and difficulties of construction. The estimates are

based upon concrete, which can be mixed on the site. Regulating works and sluices can be provided in the original river channel and the entire length of the crest may be utilized for a spillway in case of necessity.

The typical section on which the estimates are based is the ogee rising from the natural bed of the stream at an elevation of about 38 ft. above the sea level to the proposed weir sill at 98, with regulating sluices to control the higher stages. The width of the base at the deepest point is 100 ft. The ordinary stage of water at the foot of the dam is about 55 ft. above sea level, while extreme low water is about 45 ft.

There are various locations on the river where dams may safely be placed for variations of project. Taking these in order, coming down stream, the first may be at Castillo, where the river flows over ledges of basalt, which is somewhat jointed, giving it the appearance of being stratified, but it is believed to be firm and strong. The anchorages also are good.

At Upper Machuca, three miles above Machuca, the rock is calcareous sandstone, with limited weathering. Solid rock is usually found under a few feet of sand in the river channel, but the rock in the adjacent hills is weathered down nearly to the same level as the surface of the solid rock in the channel, so that the anchorage must be in residual clay and soft rock.

The Machuca site is situated across the head of the Campana Island. It is based on fine-grained, light bluish gray rock, evenly bedded and closely resembling a fine-grained quartsite. The borings on the south banks, however, show great depth of weathering, making it desirable to shift the location further up or down stream.

Conchuda, about two miles above the Boca San Carlos, also affords a possible dam site and has been considered with a view to reduce the large amount of rock excavation incidental to the Machuca dam projects.

These estimates are based upon the same prices in each case and are submitted merely as a guide to the relative merits of the plans:

Low dam at Upper Machuca	$1,045,569	
Low dam at Lower Machuca	866,040	Crest 86.6
Low dam at Boca San Carlos	2,633,124	
	$4,544,733	
Low dam at Lower Machuca	$1,240,785	
Low dam at Conchuda	2,721,411	Crest 110
Low dam at Boca San Carlos	2,633,124	
	$6,595,320	

Both of the above schemes would require, in addition, a large amount of rock excavation in the river to create navigable channels in the pools which would be avoided by the higher single dam.

The hills to the southeast of the San Carlos River contain depressions which would have to be closed by earthen embankments to provide for the Menocal project, with weirs through the saddles. The depth to hard rock varies from probably 60 to 100 ft., but as the San Carlos embankments will be avoided by the change of the dam site to a point above the Boca San Carlos, no further discussion of its embankment line is required. It would be necessary, however, to extend the San Francisco embankment lines from Ochoa up to the left bank of the river to connect with this new location, involving heavy work.

To ascertain the character of the material underlying the proposed embankments crossing the Florida, San Francisco, Nicholson and Chanchos depressions, deep borings were made in each, which revealed the residual clay and soft rock beneath the alluvium, but in thinner strata than on the hills. The rock is only moderately hard, consisting chiefly of talcose volcanic tufa, with a thin bed of earthy limestone. The silt in these depressions and swamps apparently extends to about 10 ft. below sea level, and renders it desirable to reduce the height of the embankments as much as possible.

All the routes traverse the reach on the left bank of the San Juan from Boca San Carlos to the San Francisco near its mouth, and hence cross these lateral tributaries, but at different elevations, dependent upon the number and location of the locks.

Much has been said pro and con concerning the possibility of constructing a dam at La Flor site, and the board of 1895, basing its conclusions upon certain exhibits as to geological structure, declared it inexpediate, in view of the slight advantages and the ability to construct a canalized channel at a somewhat greater cost on the left bank of the Rio Grande.

In the light of more recent borings and their interpretation by Dr. Hayes, this Commission is of opinion that a dam at this point is practicable.

The summit level would terminate at Bueno Retiro, about 9 miles from the lake, where the topography is well adapted for the purpose, as it affords opportunities for spillways directly into the bed of the Rio Grande and Guachipilin and a good lock site. Here a small ovoidal hill rises from the bottom of the valley, "composed of a calcareous shale, more or less disintegrated, but sufficiently firm for foundation purposes." The rock is about 50 ft. above sea level, and comparatively little silt would have to be excavated to place the foundations. The regulating works with the lock will close the summit level, making it unnecessary to build a dam at this site.

On the route selected as a basis for the estimate, it is proposed to construct six locks of 18.41 ft. lift each on the eastern division, giving a total of 110.46 ft., and four locks of 29 ft. lift each on the western division, giving a total of 116 ft., the difference of 5.51 ft. being due to the difference in rise of tides in the two oceans.

In estimating the cost of the locks, the large Poe lock at the Sault Ste. Marie Canal, at the outlet of Lake Superior, was taken as a standard, and the dimensions of lock chamber, fore and tail bays, gates, culverts, etc., were modified to adapt them to the present requirements.

The lock pits were extended to 15 ft. below the floor to provide for the culverts and valves and the necessary foundations.

The following are the dimensions used for one of the 18.41-ft. lift locks:

Number of culverts	4
Length of floor and side walls	939.5 ft.
Width of floor in the clear	80 "
Height of side walls, lift, draft 4 ft.	52.41 "
Length of sides between abutments	601.75 "
Width of side walls at top	10.00 "
Width of side walls at bottom	21.53 "
Width of abutment walls at quoins	31.77 "

On the western division the topography is such that the best results are obtained by the use of four locks having the same dimensions as to length and breadth, the only modification being in the lift and thickness of the walls and foundations.

Upon this basis the six locks on the eastern division will cost	$9,560,400
The four locks on the western division will cost	7,412,580
Making the total cost	$16,972,980

The amount of dredging for the two harbors not included in the table, which should be added to the totals, is, for Greytown, 10,748,900 cu. yds., and for Brito, 9,500,000 cu. yds. The jetty and other harbor work is not included in the table, but it is stated in the estimates.

For the route recommended by the Commission, passing to the north side of Silico Lake, following the left bank of the San Juan and Rio Grande rivers, and having a bottom width of 150 ft., with ten locks and one dam, the quantities from ocean to ocean, exclusive of the railroad, are:

	Cu. yds.
Dredging, river and coastal plain	61,738,842
Dredging, lake and harbors	37,557,750
Earth excavation and embankment	29,907,996
Disintegrated rock	15,248,312
Solid rock	7,573,992
Rock under water	754,878
	152,781,270

As a basis for estimating the cost of the canal, the Commission concludes that the prices on the Chicago drainage canal, with the cost of railway work in Costa Rica and elsewhere in Central America, furnish the best available guide. In view of the possible difficulty of securing sufficient labor, etc., the Commission increases the Chicago prices 33⅓% for all earth and rockwork on the Western Division, and by 50% on the Eastern Division, after allowing an increase of 10 cts. per cu. yd. on rock excavation on the Eastern Division owing to local conditions. The final prices adopted in the Commission's estimate are, therefore, as follows:

Eastern Division.

For Graytown Harbor, dredging, per cu. yd.	$0.25
For Graytown Harbor, jetties, per cu. yd.	2.50
For dry earth excavation, per cu. yd.	.44
For solid rock excavation, per cu. yd.	1.30
For dredging in upper river, per cu. yd.	.30
For dredging in lake, per cu. yd.	.20
For rock under water, per cu. yd.	5.00
Timber cribs, per cu. yd.	3.25
Clay puddle and back filling, exclusive of cost of excavation, per cu. yd.	.50
Concrete in structures other than locks, per cu. yd.	8.30
Concrete in locks, per cu. yd.	7.23
Stone pitching on embankments, per sq. yd.	2.00
Timber in structure, B. M.	60.00
Clearing, per acre	75.00
Clearing and grubbing, per acre	100.00

Western Division.

For dry earth excavation, per cu. yd.	.39
For solid rock excavation, per cu. yd.	1.03
For dredging harbor, per cu. yd.	.20
For rock under water, per cu. yd.	5.00
For jetties, per cu. yd.	2.00
Timber cribs, per cu. yd.	3.00
Clay puddle and back filling exclusive of cost of excavation, per cu. yd.	.50
Concrete in structures other than locks, per cu. yd.	8.30
Concrete in docks, per cu. yd.	7.23
Stone pitching on embankments, per sq. yd.	1.75
Timber in structures, B. M.	60.00
Clearing, per acre	75.00
Clearing and grubbing, per acre	100.00

The prices for structural work of locks and weirs are based on the cost of similar work in the United States, to which 33% has been added for difference of location, including climate, etc.

After a careful analysis and comparison of the physical features and quantities affecting the various variants, the Commission has selected that route which it believes will give the best results. This route, starting from the harbor at Greytown, crosses the coastal plain, passes to the north of Lake Silico, and up the left bank of the San Juan to the dam at Boca San Carlos, thence follows the improved river channels, crosses the lake and traverses the valleys of the Lajas and Rio Grande to Brito on the Pacific. It is characterized by six locks on the eastern division having a lift of 18.41 ft., all lying east of the dam, and four locks on the western division having a lift of 29 ft.

The summit level extends from the lock .43 of a mile east of the beginning of the cut at Boca San Carlos to the lock 1.86 of a mile west of Bueno Retiro, a distance of 139.3 miles. The details of the estimate are stated in the reports of the assistants hereto appended, and it will suffice here to summarize and classify the quantities for the excavation of the canal trunk and to affix their unit prices in order to ascertain the approximate cost. The auxiliary works have also been computed for each subdivision separately and in detail, but the totals only are stated in this connection. The calculations are based upon a minimum elevation of 104 for the summit level, with a depth of 30 ft., and a minimum bottom width of 150 ft., as set forth more particularly under the "Dimensions of the Canal."

General Estimate of Cost.

East side with 50% over Chicago prices for earth and rock.

Classification.	Cu. yds.	Price.	Amount.
Earth	23,206,836	at $0.44	$10,211,007
Rock	1,309,375	at 1.30	1,702,187
Rock under water	472,700	at 5.00	2,363,525
Dredging harbor	10,748,900	at .25	2,687,225
Dredging lake	17,308,850	at .20	3,461,770
Dredging river and canal	46,555,742	at .30	13,966,722
Dredging upper river	15,183,100	at .39	5,921,409
Total	114,785,508		$40,313,846

West side, with 33⅓% over Chicago prices.

Earth	21,949,472	at .39	8,560,294
Rock	6,264,617	at 1.03	6,452,555
Rock under water	281,673	at 5.00	1,408,365
Dredging harbor	9,500,000	at .20	1,900,000
	37,995,762		$18,321,214
	152,781,270		$58,635,061

Auxiliary Work.

Amount brought forward	$58,635,061
Jetties, Graytown, 550,000 cu. yds., at $2.50	1,375,000
Jetties, Brito, 144,107 cu. yds., at $2.00	288,214
Total last two items	$1,663,214
Concrete dam and regulating works at Boca San Carlos	$4,570,340
Four locks on west side, 28 ft. lift	7,412,580
Six locks on east side, 18.41 lift	9,560,400
Weirs on west side, Bueno Retiro	1,102,300
Weirs on east side, below San Carlos	207,800
Clearing and grubbing (7,463 acres)	615,625
Guard gates, timber piers, piling, etc.	1,089,343
	$24,558,478
	$84,856,753

Miscellaneous.

100 miles of R. R. for construction purposes at $50,000 (double track)	$5,000,000
Sanitary and police	2,000,000
For maintenance of harbors during construction of canal and for buoys, beacons and lighting	1,000,000
	$92,856,753
Engineering and administration, 6%	5,571,405
	$98,428,158
General contingencies, 20%	19,685,632
	$118,113,790

Remarks on Estimates.

For the cost of engineering and administration an estimate of 6% has been made. This estimate is large, but in a work of such great importance the engineering and superintendence must be thoroughly and carefully done by men of ability and integrity, who will necessarily command higher rates of pay than would be deemed sufficient in the United States.

An estimate of 20% for contingencies has been made. It is intended to cover all items of expense due to unforeseen accidents or emergencies. Owing to the extent and character of the work, there are more uncertainties than usual, including that of labor, which will have to be largely imported from the islands of the West Indies and from our Southern States. No work of this character and importance has ever been completed within the tropics. There is, therefore, nothing to serve as a precedent or guide for the proper contingent percentage, but after careful consideration and with a desire to make an ample allowance the board has decided to include an estimate of 20%, which is believed to be quite sufficient for all probable accidents or emergencies. It is believed that if honestly and properly administered, with money at command as required, the canal can be built within the limits of the above estimate.

The conclusions of the Commission are as follows:

The Commission, after mature deliberation, has adopted and estimated for the route from Brito to Lake Nicaragua, called Child's route, variant No. 1, and from the lake to Greytown, that called Lull route, variant No. 1. This line, leaving Brito, follows the left bank of the Rio Grende to near Bueno Retiro, crosses the western divide to the valley of the Lajas, which it follows to Lake Nicaragua. Crossing the lake to the head of the San Juan River, it follows the upper river to near Boca San Carlos, thence, in excavation, by the left bank of the river

to the San Juanillo, and across the low country to Greytown, passing to the northward of Lake Silico. It requires but a single dam, with regulating works at both ends of the summit level.

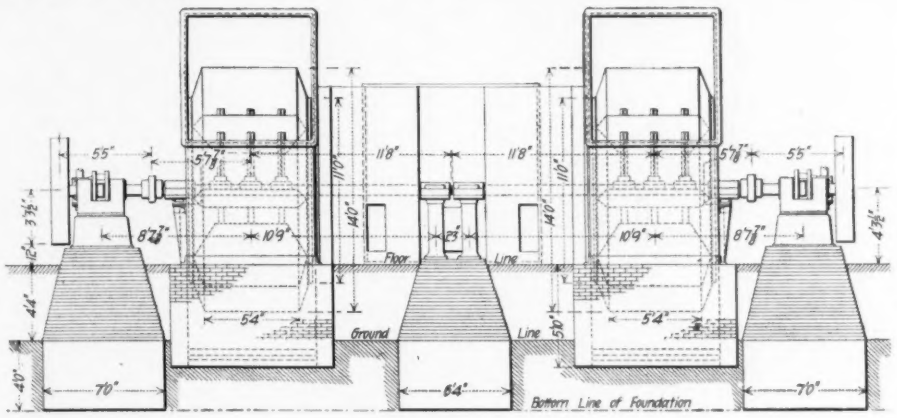
The new location selected for the dam at Boca San Carlos eliminates one of the most serious engineering difficulties by avoiding entirely the San Carlos River, with its torrential floods and large volume of sediment, and by locking down immediately from this dam the difficulties and risks of the high embankments of the Menocal line are also avoided.

Instead of the dam at La Flor, a lock and regulating works have been substituted at Bueno Retiro, where the topography is well adapted for the purpose. It is also proposed to divide the surplus waters of the lake basin between the east and west sides, thus reducing the velocities in the San Juan and securing ample wasteway capacity for the maximum discharge that can ever occur, if stored and distributed over a short period of time. Ample provision has also been made for a possible fluctuation of the lake of 6 ft. or more without injury to property by fixing the elevation of the bottom of the canal sufficiently low to cover seasons of minimum rainfall.

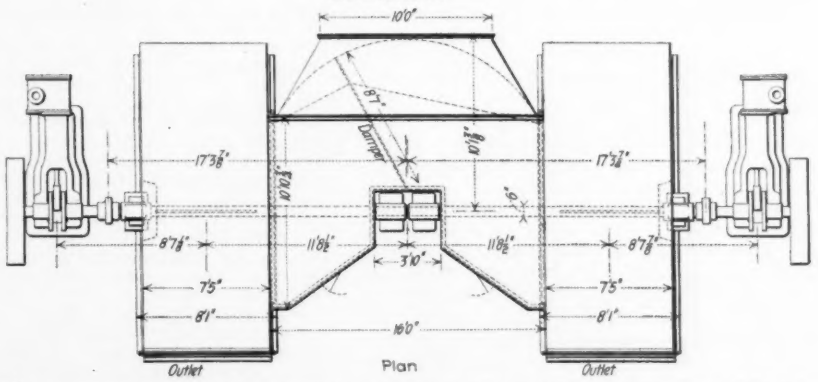
cago drainage canal, which represent cost of plant, prices paid for work done, and contractors' profits, were taken. Up to this point the Commission dealt only with facts. To the prices paid at Chicago certain percentages have been added for the difference in location, climate, etc., etc. These percentages are, of course, a matter of judgment, upon which many men may honestly differ. But from all the information obtainable by this Commission and after careful consideration, with a desire to arrive at a proper conclusion, those used in the estimate are deemed fair and reasonable.

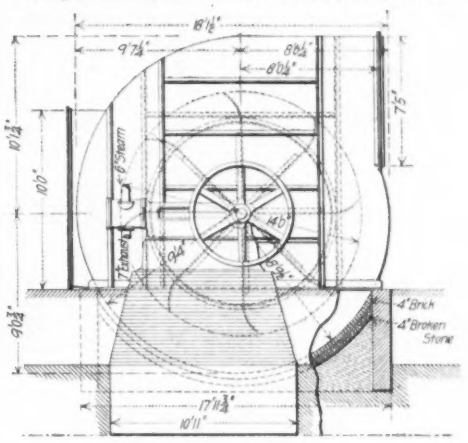
In obtaining the estimate for cost of locks the prices actually paid for building the Government locks at the Sault Ste. Marie were taken, and 33% was added for the difference of location. This percentage is believed to be ample, as a large part of the expense of constructing the locks will be for material, much of which can be furnished in Nicaragua at the same or only a small advance upon the prices in the United States.

After giving the due weight to all the elements of this important question and with an earnest desire to reach logical conclusions, based upon substantial facts, the Commission believes that a canal can be built across the



Side Elevation.





Sectional End Elevation.

A LARGE MECHANICAL DRAFT INSTALLATION.
Buffalo Forge Co., Buffalo, N. Y., Builders.

(B. W. G.) gage sheet steel. They are thoroughly and stiffly braced with angle iron, the base angle at the floor line being 4 × 6 ins., and the horizontal and vertical angle iron bracings 3 × 3 ins. The housings are thoroughly painted throughout the interior with asphaltum.

As will be seen in the illustration, the blast wheels have eight floats, and are also constructed of No. 8 gage sheet steel. They have three spiders with cast hubs, and 3 × 4-in. T-iron, with shafts 5½ ins. in diameter. The wheels are also thoroughly painted with asphaltum, and are equipped with improved water-jacketed bearings. The shafts are fitted with suitable one-half flange couplings, and are connected directly to engine shafts. The sheet steel connection between the inlets of the two fans is equipped with proper dampers for controlling the intake of either or both fans at the main intake.

To operate the fans there are two center-crank horizontal engines of the enclosed type arranged to run in oil. These engines have the following dimensions: Cylinders, 15 × 15 ins.; diameter of engine shaft, 7 ins.; crank-pin diameter, 7 ins.; length, 5½ ins.; diameter of steam supply, 6 ins.; diameter of exhaust pipe, 7 ins.; main bearings, 7 × 10¾ ins.; total weight of each engine, 15,000 lbs.

Each engine is also equipped with a flywheel and a suitable cast-iron sub-base, Nathan sight feed lubricator, Nathan automatic sight feed oil cups, oil guards, oil gages, water relief valves, and cylinder drips.

The engines have balanced piston valves, which are so constructed as automatically to take up any wear in the valve or valve seat and prevent leakage of steam. Each engine is entirely enclosed and operated in oil, and is so framed and constructed as to run without throwing oil. The crank shafts are steel, forged in one piece with iron counterbalance disks solidly fitted to them, and have forged steel connecting rods.

The fans have a common intake 10 × 10 ft. and separate outlets 7 ft. 5 ins. square. Their shafts are not connected, and a damper, previously mentioned, is arranged in the intake so that the fans may be operated independently, if desired. For the material from which this description has been prepared we are indebted to the Buffalo Forge Co., and Mr. T. C. Maxfield, its New York representative.

The surveys have in general revealed better physical conditions than were hitherto supposed to exist, especially as to the amount of rock in the upper river, whereby it is possible to greatly reduce the estimated cost of construction.

This fact will account largely for the comparatively moderate amount of the estimate when the enlarged dimensions of the project are taken into consideration.

Other reductions are due to the improved methods and machinery available, as developed on the Chicago drainage canal, and which cannot be ignored in discussing a work of this magnitude.

The creation of sufficiently capacious interior harbors presents no unusual difficulties, and they can be secured at a reasonable cost.

The field work, under the authority of the Commission, has been carefully and well done, and is believed to be all that is necessary for the preliminary location of a canal and to determine, within narrow limits, the final location of dams, locks and other constructions.

Should a canal across Nicaragua be authorized it will be necessary to make further minute and careful investigations by borings to determine the exact location of locks and dams, for which this Commission has neither the time nor money, nor would it have been justified in doing work of this character until the construction of a canal was assured.

The computations of amounts to be excavated have been carefully made and checked to guard against errors, and are believed to be accurate within narrow limits.

All possible information has been sought with regard to cost of similar work in the United States and in Central America, and a careful comparison made of the probable differences between Nicaragua and the United States.

To determine the proper unit prices for excavation the average of prices actually paid to contractors on the Chi-

isthmus on this route for a sum not exceeding that stated in the estimate.

The dimensions of the canal proposed are much larger than any hitherto considered, and will be ample not only to meet the present requirements of commerce, but also for many years to come. A navigable channel of smaller dimensions than those proposed, only sufficient for present needs, can be constructed for a lesser sum if deemed expedient.

Report signed by J. G. Walker,
Rear Admiral U. S. N., Pres. of Commission.
Lewis M. Haupt,
Civil Engineer, Member.

In appending my signature to this report, I desire to state that I concur generally with the views expressed, but my estimate of the cost is $134,818,308.

Peter C. Hains,
Colonel U. S. Corps of Engineers, Member.

A LARGE MECHANICAL DRAFT APPARATUS FOR A MEXICAN MINING PLANT.

One of the largest mechanical draft installations ever made, and certainly the largest ever installed in Mexico, was recently furnished to the Compania Metalurgica Mexicana by the Buffalo Forge Co., Buffalo, N. Y. The equipment, the general construction of which is clearly shown in the accompanying illustration, forms part of the boiler plant at the company's mines at San Luis Potosi, Mexico.

The two fans are three-quarter housing steel plate exhaust fans, with horizontal discharge, having blast wheels 14 ft. in diameter, and 7 ft. wide. The fan housings are built throughout of No. 8

A TYPE OF THREE-CYLINDER VERTICAL GAS ENGINE.

In Engineering News for May 4, 1899, was given an illustration and brief description of a 650-K-W. gas engine which has been operated for some time at the works of the Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

We present herewith several views which illustrate the general construction of this type of gas engine and some of the minor details.

Fig. 1 gives an idea of the main features, and includes a longitudinal section which affords an excellent idea of the interior arrangement of cyl-

inders, pistons, etc. It will be noticed that the main working parts are entirely enclosed by a suitable casing, which gives the machine an appearance much the same as the familiar Westinghouse steam engine. This casing supports in its inside the two main and two intermediate bearings. These intermediate bearings are provided with a wedge device for taking up wear, the construction of which is well shown in Fig. 2.

The cylinders are water-jacketed throughout

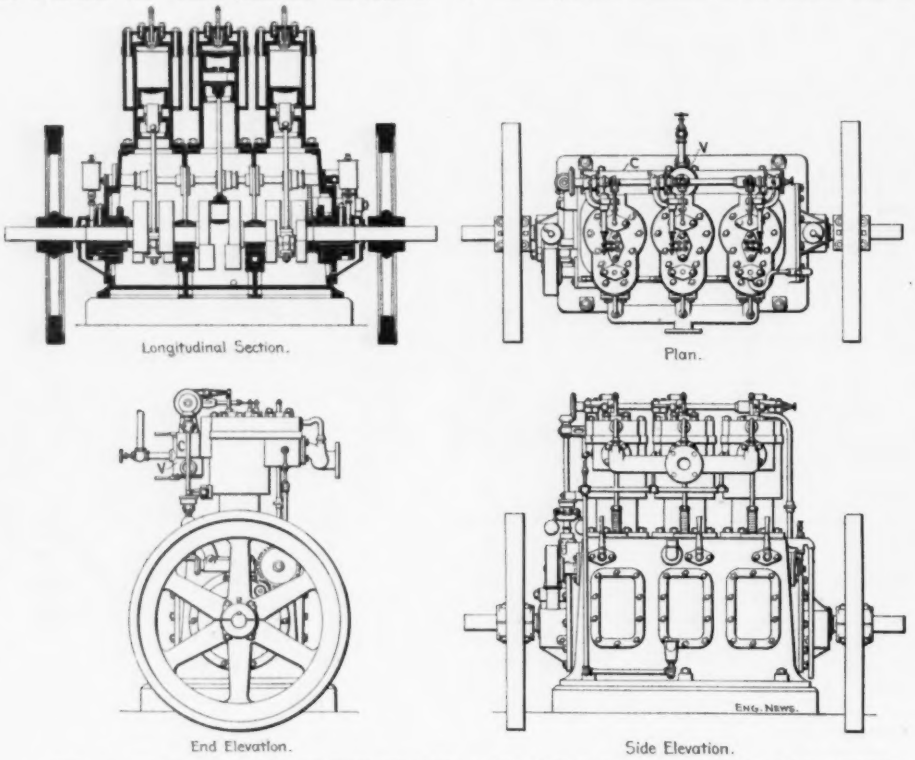


FIG. 1.—PLAN AND ELEVATIONS OF THE 3-CYLINDER WESTINGHOUSE GAS ENGINE.
Westinghouse Machine Co., Pittsburg, Pa., Builders.

their working length, as are also the cylinder heads. The pistons, Fig. 3, are long, with four spring packing rings and an additional ring at the lower end to prevent too much oil working up into the cylinder. The piston rod works on a heavy pin slipped through the piston. Provision is made for taking up wear in the brasses of the upper end of the piston rod by screwing up a wedge. Fig. 3 illustrates how this is done. The hole in the piston comes opposite the closed hole in the cylinder wall at the lower end of the stroke.

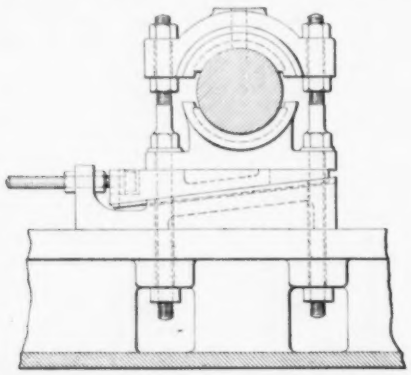


Fig. 2.—Details of Center Bearing, Showing Method of Taking Up Wear, Westinghouse Gas Engine.

The screw-plug can then be removed and the socket-wrench inserted, as shown in the figure.

All parts subject to the heating effect of compression and the exploded gas mixture are well jacketed; the cooling water finally running into the exhaust pipe.

The cranks are of forged steel, and in the smaller sizes are made in one piece. They are balanced by having heavy cast-iron blocks bolted to them, the bolts being secured so that they cannot possibly work loose. The flywheels are heavy, with solid rims and split hubs, which insures a tight wheel and one easily removed when desired. The cranks are set 120° apart.

The valves are all operated by a train of spur gears which also drive the vertical shaft upon which the centrifugal governor is mounted. Any movement of the governor balls due to a change in speed affects the single mixing valve, shown at V, Fig. 1, permitting a larger or smaller quantity of the explosive mixture to be drawn into the mixing chamber, a long box-like chamber, C, Fig. 1, connecting with each cylinder through a suitable poppet admission valve.

Electric ignition is used for reliability and convenience of repair; two sparking contacts are used, both of which are mounted in a slip plug which can be readily removed in case of a failure to operate, an accident likely to occur in any form of electric igniter. These duplicate igniters are operated from the shaft which operates the inlet valves; the exhaust valves, all opening into a common exhaust pipe, are actuated by a separate shaft inside the crank case. All the valves are of the poppet type, so designed that they are readily accessible for examination or repair, all being mounted on the outside of the cylinder heads. The regulation is claimed to be about 2% from no load to full load, referring, we suppose, to average speeds.

In gas engines of this size it is necessary to provide some means of starting; that is, turning the engine over until a first or second explosion occurs. With the Westinghouse engine this is accomplished by means of compressed air, which is stored in a tank while the engine is operating. For this purpose a small 3½ × 4-in. belted compressor, also arranged for hand operation, is provided and belted to the engine for a few minutes after starting up. The air storage tank is specially made and is much like an ordinary kitchen range boiler. With the larger sizes of engine two or more of these are used.

In starting up, the small levers seen in the rear elevation of Fig. 1 are thrown over, thus preventing the compression of the air in the cylinders. A small handle at the end of the inlet shaft is pulled and the cam operating the inlet valve of the end cylinder is thus thrown out of action. Air is then admitted from the compressed air reservoir and the engine turned over once or twice with the right cylinder acting as an air motor. By this time sufficient momentum has been acquired and the inlet valves and compression levers are thrown, thus starting the cycle of explosions and putting the engine into service.

Careful tests and data obtained from engines in actual commercial operation show that the average consumption is 11 cu. ft. of natural gas per horse power, or ⅛ gallon of gasoline per horse power per hour. As natural gas has a heat equivalent of about 1,000 heat units per cu. ft., the consumption of illuminating or other gas can be determined approximately for any locality by knowing the character of gas to be there obtained.

Fig. 4 is a view of a 350-HP. gas engine set up ready to undergo a test under full load conditions, and incidentally gives an idea of a portion of the testing department where all the various types of Westinghouse steam engines are tested.

In this work a supplementary brake wheel is keyed to the engine shaft. This wheel has inside flanges forming a circular trough which is flooded with running water to remove the heat produced by the Prony friction brake. Indicator cards are taken under full load, and the proper working of all parts assured before the test is regarded as complete.

ANNUAL CONVENTION OF THE ROADMASTERS' ASSOCIATION OF AMERICA.

The 17th annual convention was held Sept. 12 to 14 at Detroit, Mich., the headquarters being at the Cadillac Hotel. At the opening meeting on Sept. 12 the Mayor of Detroit, Mr. Maybury, delivered an address of welcome, and Mr. T. Hickey (Mich. Cen. R. R.), the President of the association, delivered a brief opening address. Short speeches were also made by Mr. Doyle (C. & West. Mich. Ry.) and Mr. Hawkins (Norfolk & Southern Ry.)

The first part of the technical proceedings was in regard to the adoption of standards by the association. Mr. C. E. Jones (C., B. & Q. Ry.) expressed himself very emphatically in favor of such action, stating that roadmasters ought to have the strength of their convictions to say what they consider right and wrong in matters relating to the track. He thought they should take a stand in such matters, and not rest content with mere discussions. It was resolved to appoint a committee to consider and report upon the question of standards.

The report of the Executive Committee was then read, after which Mr. J. B. Dickson (C. & N. W. Ry.) read his report as Secretary and Treasurer. The receipts for the past year amounted to $1,530, and the expenditures to $1,556, leaving a balance of $738 in the treasury. The election of officers was then proceeded with, and after Mr. Dickson had declined the nomination for president, the list elected was as follows: President, S. B. Rice, Richmond, Fredericksburg & Potamac Ry., Richmond., Va.; First Vice-President, D. Foley, Michigan Central R. R., Jackson, Mich.; Second Vice-President, V. T. Douglas, Chesapeake & Ohio Ry., Richmond, Va.; Secretary and Treasurer, J. B. Dickson, Chicago & Northwestern Ry., Sterling, Ill.; Member of Executive Committee, John Doyle, Chicago & West Michigan Ry., Grand Rapids, Mich.

A letter from Mr. F. R. Coates (N. Y., N. H. & H. R. R.) was then read, suggesting the change of name to the "Railway Maintenance of Way Association," and also suggesting a consolidation with the Eastern Maintenance of Way Association. This communication was referred to the Executive Committee.

The report of the committee on "Increasing the Length of Rails, Using Miter Joints and Determining the Difference in Expansion of Light and Heavy Rails" were then

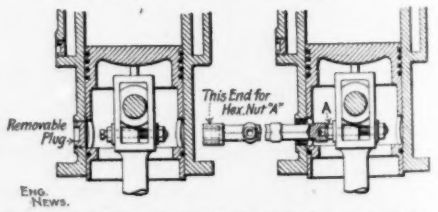


Fig. 3.—Section of Part of Cylinder and Piston, Showing Method of Taking Up Wear in Upper End of Connecting Rod, Westinghouse Gas Engine.

presented. An abstract of this was given in our last issue. There was but little discussion. Mr. Foley (Mich. Cen. R. R.) said that 60-ft. rails could be straightened as well as 30-ft. rails, but at greater cost, and Mr. Carhart, of the Illinois Steel Co., made some remarks as to rail mill practice. At the afternoon session, the discussion was continued. Mr. Jones (C., B. & Q. Ry.) did not see why there should be more labor in surfacing 60-ft. rails than 30-ft. rails, but Mr. Douglas, for the committee, stated that this was found to be the case. On motion of Mr. Hawkins (Norf. & So. Ry.), it was decided to strike out that clause of the report which recommended the use of 33-ft. rails.

There was no report from the committee on "Rail Joints," and the next report presented was that relating to "Standard Right of Way Fences," which has already been given in our columns. In the brief discussion, Mr. Doyle (C. & W. M. Ry.) referred to the fact that in some states the style of right-of-way fence was regulated by law, and that in Michigan the Railroad Commissioners have approved of the use of woven wire fences. Mr. Brown (Chf. Eng., F. & P. M. Ry.) approved of the report, except in so far as it recommended a specific make and specific spacing of wires for woven wire fences. He considered that the

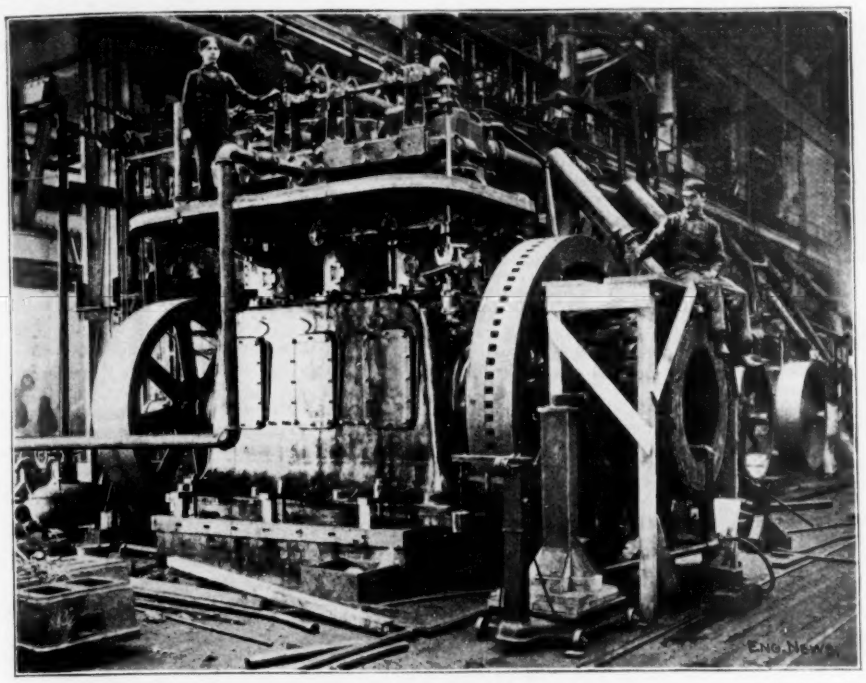


FIG. 4.—TESTING A 350-HP. GAS ENGINE, SHOWING ALSO DEPARTMENT FOR TESTING STEAM ENGINES.

association might recommend a certain type of fence, but should not bind itself to any particular style or make. It was decided to amend the report in accordance with this idea.

Mr. W. T. Manning, Consulting Engineer of the Baltimore & Ohio R. R., was then invited to describe his patented form of unsymmetrical rail section, which was described in Engineering News some months ago. He referred to the experience with it, and to the economy resulting from its longer life, which, however, seems to be confined mainly to curves. He also referred to the serious question of the quality of ordinary modern rails. He has found old 67-lb. rails now in use to be of better quality and greater durability than modern rails of greater weight. The latter do not get a proper amount of manuipulation, and as they are reduced to the finished section in the same number of passes, they leave the rolls very much hotter than the lighter rails, and are consequently of inferior quality.

A brief discussion on ties was started by Mr. Doyle, who considered the tie question as being now more important than the rail question. It is a problem where the tie supply will be found in the next ten years, and the association ought to have the actual experience of roadmasters using treated ties. A few members spoke in reference to such ties, but did not give any definite information. One gentleman stated that the burnetizing process consisted of dipping ties in open vats, while in the creosoting process the ties were treated under pressure. Nobody controverted this decidedly novel, and quite erroneous idea. Mr. Jones referred to the fact that the ties now obtained are of inferior quality to those obtained years ago, and stated that his road, the C., B. & Q. R. R., is about to experiment with treated ties. The meeting then adjourned.

On Sept. 13, the first report presented was one on "The Embellishment of Station Grounds," by Mr. M. Sullivan (Mich. Cen. R. R.), of which the following is a brief abstract:

The Mich. Central R. R. is following the practice of beautifying the surroundings of stations along its whole line. At Niles are the headquarters for all this work on the western division, including 170 miles of road. There are greenhouses, and 10 acres of land for landscape gardening. The cost of maintenance of the greenhouse and its surroundings is $325 per month in the summer, and $125 per month in the winter, or about $2,700 per year. This includes flowers and shrubs for the dining cars, and the bouquets which are given to all passengers on all first-class trains during the stop at Niles. For other stations, the cost is comparatively small. The grounds should be leveled off, rolled and well raked, gravel walks neatly marked out and all unnecessary and unsightly buildings removed. The station building should be kept in good condition, neat and clean, to correspond with the appearance of the grounds. All such work has a good effect upon the station agents, section foremen and others in inducing them to keep the grounds and right of way neat and in good order.

Mr. Jones (C., B. & Q. R. R.) had effected great improvements in the appearance of the right of way at very little cost. He did the work on his own authority, but it was so satisfactory that it met with he approval of the superior officers. He suggested that the right of way should be sown to grass, and the grass or hay sold to farmers. Mr. Hawkins (Norf. & Sou. Ry.) said that his road had not much money for this kind of work, but is making a beginning by having the stations kept neat and trim. Mr. Rice (R., F. & P. Ry.) said his road gave attention to the section-house grounds as well as to the station grounds.

Mr. Dickson (C. & N. W. Ry.) said that the station agents attend to the lawns, shrubs, etc., and the roadmaster has the gras cut on the lawns at frequent intervals. His road is also doing considerable work in sodding slopes, to improve their appearance as well as to consolidate them and protect them from washing. Mr. Cornell (C. & N. W. Ry.) referred to a practice of paving the ditches with loose stones and whitewashing them. Mr. A. Torrey, M. Am. Soc. C. E., Chief Engineer of the Michigan Central R. R., also made some remarks as to the work of improving the appearances of the right of way along his road.

A paper by Mr, F. R. Coates (N. Y., N. H. & H. R. R.) on "The Relations of Track to Traffic" was then read, and also a paper by Mr. C. C. Dunn (Seaboard Air Line), on "Standard Car and Track Gages." There was no discussions on these papers, abstracts of both of which were given in our last issue. The meeting then adjourned.

In the afternoon a large number of visitors went by special train on the Flint & Pere Marquette R. R. to Delray, to see a new tie-spotting machine invented by Mr. G. M. Brown, Chief Engineer. This machine has saws which cut grooves to guide the section men in adzing out seats for the rails or tie-plates. There was also a trolley car excursion around the city. In the evening, Mr. E. E. Russell Tratman, Assoc. M. Am. Soc. C. E. (Associate Editor of Engineering News), delivered an address upon "Modern Improvements in Track and Track Work," illustrated by a number of stereopticon views of devices and views of track.

On Sept. 14 there was an early excursion to the works of the Detroit Graphite Co. The first proceeding of the business meeting was the election of Mr. Tratman as an Honorary Member of the association. Then came the voting upon the place for the next meeting, which resulted in the selection of Los Angeles, Cal. In view of the climate of California, it was also voted to hold the meeting on the second Tuesday of November, 1900. Brief addresses were then made by the new officers, after which the meeting adjourned. In the afternoon there was an excursion steamer to the St. Clair flats, where dinner was served.

The Road and Track Supply Association had a large and varied exhibit of track appliances, tools and supplies, particulars of which are given in our supplement. This association elected officers as follows: President, R. L. Thomas, National Lock Washer Co., Newark, N. J.; Vice-President, H. T. Wallace, Diamond State Steel Co., Wilmington, Del.; Secretary, J. Alexander Brown, Pocket List Publishing Co., New York, N. Y.; Members of the Executive Committee, E. G. Fisher (American Steel & Wire Co.), F. H. Ingalls, Buda Foundry & Mfg. Co.), Wm. Goldie (Dilworth & Porter), W. W. Worthington (Q. & C. Co.), Henry Elliott, Jr. (Elliott Frog & Switch Co.), R. J. Davidson (Ramapo Iron Works).

ANNUAL CONVENTION OF THE NEW ENGLAND WATER-WORKS ASSOCIATION.

The eighteenth annual convention of the association was held at Syracuse, N. Y., Sept. 13 to 15, inclusive. It was the first meeting to be held outside the New England states, the constitution having been amended to permit going to other sections of the country. The membership, it may be explained, is not limited to New England, outside members having all the privileges of the association, except holding office, and there being a large membership throughout the United States and Canada. There are rumors that one of the next important changes in the constitution will remove even this limitation.

The convention opened with the president, Mr. F. F. Forbes, of Brookline, in the chair, and with Mr. J. C. Whitney, of Newton, in his accustomed place in the secretary's chair. Mr. Wm. R. Hill, M. Am. Soc. C. E., introduced Mr. Jas. McGuire, Mayor of Syracuse, who welcomed the association to the city. He commended Mr. Hill for the able and faithful manner in which he had filled the position of engineer and superintendent of the water-works of Syracuse, and said that whatever political changes might occur, no party would dare to try to get along without Mr. Hill. The speaker thought the recent history of the Syracuse water-works a complete justification of municipal ownership. Before the city bought the works the service was poor, the water bad and the rates high. The rates are now half lower than under private ownership, the water remarkably pure and good, and the service eminently satisfactory. An answer to one of the arguments most strangely urged against municipal ownership, that the system will break down because of the employment of so many men, is the fact that Syracuse has had an unusually large number of men at work on extensions made by day labor, and still the works are successful.

President's Address.

Mr. Forbes, in his annual address, called attention to several reforms which he thought would increase the already high standing of the association. He thought the Journal should be made a more important means of registering progress in water-works affairs; that there should be a secretary to give his whole time to the association, acting also as one of the editors of the Journal; and that there should be a yearly appropriation of at least $100 to add books to the library.

Finances and Membership.

The report of the treasurer showed a balance of $2,712. The net gain in membership during the year was only two, there now being 572 members; of these 494 are active, 5 honorary and 73 associate.

Removing Vegetable Organisms from the Syracuse Reservoir.

By Wm. R. Hill, M. Am. Soc. C. E., Engineer and Superintendent.

The means employed to the end stated were described in Engineering News for May 25, 1899. Skimming has been kept up during the present season, and there has been no trouble from tastes and odors. One man removes about eight quarts of organisms and other floating matter each day. Mr. Allen Hazen, Assoc. M. Am. Soc. C. E., expressed disappointment that no information was given regarding the species of organisms that develop in the water, and asked if any examinations had been made to determine their kind. Mr. Hill said no. Mr. John C. Haskell said that he had tried skimming, but was not sure whether the absence of trouble at just that time was due to the skimming or some other cause.

The New Filter Plant at Albany, N. Y.

By Allen Hazen, Assoc. M. Am. Soc. C. E., New York city.

Mr. Hazen showed a large number of lantern slides of the plant, accompanying them with appropriate comments. The plant is now in use. The estimated cost was $478,000 for covered filter beds of 16,000,000 gallons daily capacity, sedimentation and pure water basins, low lift pumping station and over a mile of large steel force main. The final estimates have not been completed, but it is known that the purification works proper will not exceed the estimates, and that the other parts of the work will do so slightly. The plant was described in detail in Engineering News for Feb. 10 and Oct. 20, 1898.

The New Hydraulic Laboratory at Cornell University.

By Prof. E. A. Fuertes.

Profesor Fuertes said that when he assumed charge of the work in civil engineering at Cornell, one of his aims was to establish a rational system of laboratory work. He then reviewed the development of laboratory work at Cornell and in foreign countries, stating that much of that done abroad was of little advantage to the students, the laboratories serving chiefly the personal ends of the professors. He then described the new Cornell laboratory with the aid of lantern slides. (See Engineering News,

March 2, 1899, for full illustrated description of the laboratory and an outline of the proposed work.) The laboratory thus far is a huge engine of possibilities. It is open to the world, either for work to be done by independent investigators, or by the University staff. The main conditions of use will be that new work shall not interfere with that previously started, and that the laboratory shall not be called on to bear too great expense. Already about ninety petitions for investigations have been received, from all over the world.

Flood Water Channel of the Reservoirs of Altoona, Pa.

By Chas. W. Knight.*

The reservoirs in question are two in number, on Burgoon's Run, formed by earth embankments 3,000 ft. apart. The reservoirs have a drainage area of 9.6 sq. miles, mostly of steep mountain slopes, with a run-off of at least 66% within 24 hours after rains. The highest observed rainfall in the vicinity, on another drainage area, was about 8 ins. in 24 hours. The upper reservoir has a capacity of 65,000,000 and the lower of 355,000,000 gallons, the difference in the elevation of flow lines being 59 ft. The upper reservoir was built in 1887, and the lower in 1894-6. The flood water channel was built in 1896-7. Previous to the completion of the channel the city had expended about $20,000 in removing flood water debris from the upper reservoir, the volume of debris exceeding 20,000 cu. yds. in one day.

The channel was designed to divert the flood water from the reservoirs and prevent both their filling with debris and fouling by objectionable vegetable and other matters. The channel has a total length of 5,630 ft., including the diverting channel and the return channel to the stream below. The channel proper is 3,991 ft. long, 20 ft. wide at the bottom, with side slopes of 1 to 1 and a bottom grade of 2 ft. per 100, the depth below the top of the embankment being 8 ft. The bottom of the channel is paved with smooth dressed stone, with ¼-in. joints 15 ins. deep, resting on 6 ins. of concrete. The side slopes for the first 3 ft. are paved with rock-faced ashlar, on 6 ins. of concrete, and for 2 ft. more with a close-jointed dry wall. The diverting embankment is of earth, with a slope wall of stone above and broken stone on the lower slope. Below the channel proper is a by-wash 16 ft. wide in its straight and 20 ft. wide in its curved portions, ending in a walled creek channel 60 ft. wide.

Several emergency spillways of various dimensions are provided at different points.

Ordinarily water passes into the upper reservoir through an inlet chamber, and on to the lower reservoir. When rains make the water turbid, valves are closed and the water sent through the flood channel. Except during a few rains after a long, dry spell in the summer, it is not necessary to divert the flood water until the volume of flow exceeds 50,000,000 gallons a day.

The flood conditions, and the danger to the dams, are increased by the embankments forming the horse-shoe curve on the Pennsylvania Railroad, and the culverts through which the stream flows. These conditions, and temporary dams formed of logs, cause flood waves. In heavy storms, and with a normal flow, the velocity of the current in the flood channel is 22 ft. per sec. Sometimes, with flood waves, it reaches 27 ft. The channel and all accessories cost about $90,000.

Stand-Pipes.

By Byron I. Cook, Woonsocket, R. I.

Woonsocket has three wrought stand-pipes, or tanks, of large diameter but comparatively small heights. The first was built in 1884. The second was built in 1890, and is 50 × 35 ft. The third is 76 × 30 ft., and was built in 1892. The second has hammer-cut riveting, which the author prefers, and the third was cup-riveted. For the second stand-pipe, with a diameter of 50 ft., lime was added to the top of the foundation material, to delay setting of the cement until the bottom was all in place. The plan was not a success. The exteriors of the pipes are kept painted with Dixon graphite paint, and the interiors with Smith's Durable Metal Coating, the interiors being painted once in two years. Before the interiors are painted, they are scraped with old flat files, ground down to chisel edges and kept sharp. On the No. 3 pipe scraping has cost 9.2 cts. per sq. yd., and painting has cost (bottom one coat, sides two coats) 4.2 cts. for labor and 4.9 cts. for paint, making a total of 18.3 cts. for all the interior work.

Mr. John C. Haskell suggested that the use of a concrete bottom would save painting, and that he proposed to use one on a new structure. Mr. Geo. Bassett said that to prevent settlement of the bottom of a stand-pipe he had poured in cement grout, under a 6 or 8-ft. head, through holes in the bottom of the structure. Mr. W. C. Hawley, Assoc. M. Am. Soc. C. E., of Atlantic City, had placed the bottom of a stand-pipe on dry sand and cement, with good results, the cement gathering enough moisture to set it. Mr. Haskell had spread 2 ins. of dry cement on a foundation which had become well dried, and on placing the bottom had settled evenly. Mr. Jos. Beals had, some 13 or 14 years ago, leveled off the foundation of a stand-pipe with asphalt concrete, like that used for sidewalks. For paint, he used lead and oil on the outside, and ahphalt prepared by local varnish makers on the inside. He used to paint the inside once in two years, but now did it once in three years.

*Of the Stanwix Engineering Co., Rome, N. Y. The paper was read by Mr. C. C. Hopkins, of the same company.

Suggestions Regarding the Design of Distribution Systems.

By Prof. G. S. Williams, M. Am. Soc. C. E., of Cornell University.

The paper opened by calling attention to the common failure to divide distribution systems into high and low levels, and the advantages of such a practice. On large lines of pipe both expense and time (in closing valves) may be saved by using reducers and inserting valves smaller than the pipe. The use of Y's for blow-offs, placed so they will form mud traps, is advantageous. Branches with their tops level with the main pipes decrease the deposits in the smaller pipes. Contrary to long-accepted ideas, easy curves in pipe lines are not advantageous. Such curves should not exceed about five diameters.

The suggestions regarding the use of gates smaller than the pipe in which they are placed led to quite a discussion, the idea being new and strange to some of the members. The concensus of opinion was that on large pipes, say above 16 ins., such a practice would be advantageous, unless the available head was limited or the number of gates very large. On smaller pipes the gain in time of closing was of little consequence, and the cost of reducers might equal the saving in gates. Mr. Williams was inclined to a more liberal use of gates of reduced size than was Mr. Kuichling.

The discussion also brought out, from Mr. Kuichling, Mr. Williams and others, some interesting points regarding the use of gates as meters. The hopes of some of the members that an easy and cheap substitute for meters on large mains had been found was dashed to the ground by the explanation that each gate had to be calibrated to ascertain its discharge at a given number of openings, and that the process took from two weeks to two months of careful work, according to the variations in the particular gate, pressure and the mathematical ability of the men who made the study.

On request of Mr. Kuichling Mr. Williams gave an outline of his ideas on misconceptions regarding the effect of curves in pipe lines. He stated that most of the experiments bearing upon this subject were made at least 50 years ago, with very small pipes and numerous bends and angles. In 1886, Mr. John R. Freeman, M. Am. Soc. C. E., in connection with his experiments on fire streams, first set forth the idea that prevailing opinions were wrong. Prof. Williams did not care to go far into the subject until he had carried his studies further.

The Care of Fire Hydrants in Winter.

By Geo. I. Bailey, Albany, N. Y.

The city of Albany has about 800 fire hydrants. Most of these are of local make and have a waste that is always open, even when the hydrant is in use. Before the author took charge of the works the city was divided into districts of 50 hydrants each, with a man in charge of each district. Before winter set in the space between the frost box and the stand-pipe was filled with sawdust or manure. Each hydrant was examined daily and the snow shoveled off for 10 ft. around it. In case a hydrant was found frozen, salt was thrown in to thaw it, and another visit made in the afternoon to see if it was all right. Acting on information obtained from other cities, and upon our own experience, the manner of caring for the hydrants has since been changed. Hydrants cannot freeze while empty, so they should be perfectly drained. Where there is no sewer to drain to, connection may be made to a pit filled with broken stone. Where wet ground renders this impossible the hydrant must be pumped out after being used. Instead of daily examinations, each hydrant is now examined and repaired in the fall and not touched again until spring, except in the case of doubtful ones, or where trouble occurs. In case of freezing, the hydrant is thawed by means of a portable boiler, weighing not over 30 lbs., using oil for fuel. A rubber tube conveys steam from the boiler through the nozzle into the hydrant. In 20 minutes the ice will be thawed.

It is advisable to use only one style of hydrants, as this insures interchangeability of parts and renders every one thoroughly familiar with its construction and operation. Where fire hydrants are used for other than fire purposes, a special nozzle or valve should be attached and the fire nozzle opened and kept so until the special use is discontinued. This saves wear and tear of the hydrant. Several mambers expressed unqualified approval of the principles laid down in the paper.

Methods of Assessment and Collection of Water Rates.

By F. H. Crandall, Burlington, Vt.

This paper was a comprehensive review of the many arguments, pro and con, for various methods of assessing and collecting rates. The author favored the meter system, and believed that the cost of service should be divided between public and private users in accordance with the benefit received. Meter rates were less popular formerly than now because they were not based on the principle of mutual advantage, but were intended to favor the seller of water. Since the consumer is directly benefited by having water under pressure constantly on tap he should pay something without regard to the smallness of the quantity used. Even where the water department has it in its power to shut off water for non-payment of rates, it is better to recognize some of the characteristics of the human mind and offer a slight discount for prompt payment. This is shown by the very large percentage of people who take advantage of the discount.

In the discussion the use of meters on fire supplies for manufacturing establishments being mentioned, it was stated that the Massachusetts Mutual Factory Insurance Co. insisted on having the Venturi meter, if any, on its risks. Wr. Whitney thought that while this had been laid down as a rule it might not be insisted on, in case strong opposition arose.

Mr. Hawley favored a minimum charge for the first 1,000 cu. ft. of water and a flat meter rate thereafter. Mr. Hazen suggested a minimum charge for each service (or class of services) and a flat rate thereafter. Milwaukee, he thought, was the only American city that had adopted this plan. There the consumer pays $3 a year and a flat meter rate on the whole consumption. The same plan was adopted in Berlin in April. Several members agreed in favoring a meter charge at a certain rate for the first given quantity, then a lower rate for the next additional quantity, and so on. In that way every one paid exactly the same rate for quantities up to a given amount.

The Buffalo Water-Works.

By L. H. Knapp, M. Am. Soc. C. E., of Buffalo, N. Y.

The author prefaced his paper by stating that it was designed as an aid to any who might visit the works before returning to their homes. The works were bought by the city from a company in 1868, for $705,000, that sum having been fixed by a legislative act. At that time the works might have been duplicated for $500,000. The supply is taken from the Niagara River, through two tunnels, 1,000 ft. long, terminating at the outer end in a masonry intake pier. The river at the pier has a current of 8 to 14 miles an hour. Steel shields are provided for guarding against ice, the water being drawn from the bottom of the river when the ice gives trouble. Ice elevators, driven by steam power, are also used when the slush gets into the bottom of the intake. Steam and hot water are used to melt the ice. The pumping plant has an aggregate rated capacity of 187,000,000 gallons, and includes nine pumps of from 12,000,000 to 30,000,000 gallons capacity each. The whole plant has a total of nearly 7,000 HP. It is believed to be the largest pumping plant under one roof in the world. There are 478 miles of cast-iron mains and only 1,014 meters, none of the last being on private services. The Buffalo hydrant, designed by the author over 20 years ago, is used. In winter the hydrants are protected by steel covers. A reservoir of 160,000,000 gallons capacity was built in 1893. The per capita water consumption increased from 40 gallons in 1868 to 222 gallons in 1898. It is estimated that 70% of the water pumped is wasted. Plans have been approved for a 200,000,000-gallon pumping plant and a new intake tunnel 5,460 ft. long. All city departments pay for water used, the total revenue from these sources having been $110,000 in 1898. The allowance for fire hydrants is $20 each. Public buildings pay about 2 cts. per 1,000 gallons for water used, the same as metered private consumers. The schools use large quantities of water for driving ventilating fans.

Other Papers.

The following papers were announced on the programme but not read, owing to the absence of the authors: "The Glasgow Water-Works," by Jas. M. Gale, Engineer in Chief of Loch Katrine Water-Works, Glasgow, Scotland: "Covered Reservoirs," by Freeman C. Coffin, M. Am. Soc. C. E., of Boston; "A Rumpus in Collecting Meter Rates," by Geo. F. Chace, Taunton, Mass. The first two papers were received and ordered printed. The one by Mr. Coffin was understood to be the same as recently read before the Boston Society of Civil Engineers and printed in the "Journal of the Association of Engineering Societies" for July, 1899.

Business and Pleasure.

The following officers were elected for next year: President, B. I. Cook, Woonsocket, R. I.; Secretary, Willard Kent, Narragansett Pier, R. I.; Treasurer, L. M. Bancroft, Reading, Mass.; Senior Editor, Jos. Beals, Middleboro, Mass.; Junior Editor, Chas. W. Sherman, Jun. Am. Soc. C. E., Cambridge, Mass.

The exhibit of water-works appliances is mentioned under Industrial Notes, elsewhere in this issue. It was in charge of Mr. W. H. Van Winkle, of Newark, N. J.

On the way to Syracuse many of the members visited the new filter plant of Albany, N. Y., and other parts of the works. In Syracuse there was a drive about the city and to the distributing reservoir, and an excursion to and on Lake Skaneateles; also a banquet and many other forms of entertainment for members and guests. The usual vote of thanks were not forgotton and a more substantial form of showing appreciation of the entertainment and courtesies accorded was tendered to Mr. Hill in the form of a handsome piece of furniture.